US Army Corps of Engineers

Sacramento District

Engineering Division

Sutter Basin Pilot Feasibility Report - Environmental Impact Report / Supplemental Environmental Impacts Statement

Butte and Sutter Counties, California

HYDRAULIC DESIGN APPENDIX

July 2013

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Acronyms and Abbreviations

ACE	Annual Chance of Exceedance
CNRFC	California Nevada River Forecast Center
CVFED	Central Valley Floodplain Evaluation and Delineation
CVFPP	Central Valley Flood Protection Plan
DWR	Department of Water Resources
FRM	Flood Risk Management
HEC	Hydrologic Engineering Center
HTOL	Hydraulic Top of Levee
NAD83	North American Datum of 1983
NAVD88	North American Vertical Datum of 1988
NGVD29	National Geodetic Vertical Datum of 1929
NLDB	National Levee Database
NWS	National Weather Service
PBI	Peterson Brustad Incorporated
RD	Reclamation District
SD	Standard Deviation
SBFCA	Sutter Butte Flood Control Agency
TRLIA	Three Rivers Levee Improvement Authority
ULDC	Urban Levee Design Criteria (State of California)
USGS	United States Geological Survey
USACE	United States Army Corps of Engineers
UPRR	Union Pacific Railroad
VE	Value Engineering

1.0 Introduction

1.1 Purpose and Scope

The purpose of this report is to describe the hydraulic analysis conducted in support of the Sutter Basin Feasibility Study. This report documents the analysis of the final array of alternatives. Analysis of the draft array of alternatives is described in Attachment A.

1.2 Background

The U.S. Army Corps of Engineers, together with the State of California and Sutter Butte Flood Control Agency (SBFCA) conducted this feasibility study to select a plan that reduces flood risk and provides ancillary Ecosystem Restoration and Recreation Benefits within the study area. The goal of the study is to identify a cost effective, technically feasible and locally acceptable project that best reduces flood risk and flood damages and complies with all Federal, State, and local laws and regulations.

1.3 Location

The Sutter Basin study area is located within the State of California approximately 25 miles north of Sacramento. A map of the watershed is included as Plate 1 and a map of the study area is included as Plates 2 and 3. The study area covers approximately 300 square miles and is approximately 43 miles north-south and 9 miles east-west. The study area includes the communities of Yuba City, Live Oak, Gridley, Biggs, and Sutter. Based on 2010 census data and floodplain mapping presented herein, approximately 95,000 people reside within the study area 0.2% (1/500) Annual Chance Exceedance (ACE) Floodplain. Yuba City is the largest community in the study area with a population of approximately 67,000 within the 0.2% (1/500) ACE Floodplain. A map of population density within the study area is provided in Plate 4 and tabulated in Table 1. The majority of land use in the study area is related to agricultural with rice and orchards comprising approximately 64.5% of land use. A map of land use types in the study area is presented in Plate 5 and tabulated in Table 2. The primary sources of flooding within the study area are the Butte Basin, Sutter Bypass, Feather River, Cherokee Canal, Wadsworth Canal, and local interior drainage.

Table 1. 2010 Population, Sutter Basin Study Area

Economic Evaluation Area	Population within ACE Floodplain						
	50% (1/2)	**10% (1/10)**	**4% (1/25)**	**2% (1/50)**	**1% (1/100)**	**0.5% (1/200)**	**0.2% (1/500)**
Town of Sutter	0	0	0	0	0	0	251
Yuba City Urban	0	67351	67368	67368	67368	67368	67368
Biggs Urban	0	19	1452	1452	1452	1452	1763
Gridley Urban	0	0	6379	6379	6379	6379	6379
Live Oak Urban	0	0	8362	8362	8362	8362	8362
Sutter County Rural	1089	4837	6260	6314	6323	6354	6378
Butte County Rural	0	9	4776	4788	4788	4793	4899
Total	1089	72216	94597	94663	94672	94707	95400

Table 2. Land Use Types, Sutter Basin Feasibility Study Area

Land Use Type	Acres	Percent of Total
Abandoned	0	0.0
Burned Over Areas	0	0.0
Citrus and Subtropical	960	0.5
Deciduous Fruits and Nuts	61,230	31.2
Entry Denied	0	0.0
Field Crops	3,310	1.7
Grain and Hay Crops	4,520	2.3
Idle	4,800	2.4
Barren and Wasteland	50	0.0
Native Classes Unsegregated	0	0.0
Non-irrigated Idle	0	0.0
Riparian Vegetation	10,580	5.4
Not Surveyed	0	0.0
Native Vegetation	13,110	6.7
Water Surface	2,000	1.0
Pasture	5,810	3.0
Rice	65,360	33.3
Semi Agricultural and Incidental to Ag	2,620	1.3
Truck, Nursery and Berry Crops	3,080	1.6
Urban	6,410	3.3
Commercial	640	0.3
Industrial	1,490	0.8
Urban Landscape	600	0.3
Residential	5,120	2.6
Vacant	4,520	2.3
Vineyards	70	0.0
Outside	0	0.0
Total	196,260	100.0
Sources: DWR 2004 Butte County Land Use Survey DWR 2005 Sutter County Land Use Survey		

1.4 Plan Selection Process

The final array of alternative plans described in this report were selected through a risk informed planning process involving multi-disciplinary analysis at increasing levels of detail. At each level of screening and analysis the level of detail was improved and the relative uncertainty was assessed. Measures and alternatives were carried forward if the level of detail was insufficient to screen it out.

Throughout this process the concept of absolute accuracy versus relative accuracy was considered in alternative comparisons. Although it would appear that every plan should be compared to the most accurate assessment of existing conditions, this is not necessary because the relative accuracy between plans is sufficient to select the most optimal plans to move forward.

Conceptual alternatives were developed from a broad array of measures at a qualitative level of detail. The conceptual alternatives were developed during a planning Charrette attended by the project sponsors and subject matter experts. Development of the conceptual alternatives is described in the Sutter Basin Feasibility Study report.

An array of draft alternatives were derived from the conceptual alternatives and evaluated at an increased level of detail. This level of detail included qualitative and quantitative engineering analyses. Analyses included floodplain hydraulic modeling, cost estimating, and economic benefit estimations. The level of detail was limited to that required to decide which plans to carry forward. Results were evaluated at a combined Value Engineering (VE) study and planning charette attended by the project sponsors and subject matter experts. At the conclusion of the VE and planning charette, refinements to the draft array of alternatives were identified for further, more detailed analysis. Selection of the draft array of alternatives is described in Progress Document 1.

Final alternatives were selected from the draft alternatives in the next level of detail. This level of detail included additional qualitative and quantitative engineering analyses. Analyses included refined channel hydraulic modeling, cost estimating, and economic benefit estimations. The level of detail was limited to that required to decide which plans to carry forward. Results were presented to the vertical team at Decision Point 2. At the conclusion of the Decision Point, a final array of alternatives was identified for further analysis. A summary of the hydraulic analysis performed for the draft array of alternatives is described in Attachment A. Additional details are described in internal memorandums on file within the Sacramento District Hydraulic Analysis Section.

1.5 Datum

As required by ER 1110-2-8160 all elevations provided herein are referenced to the NAVD88 vertical datum. All horizontal data provided herein are referenced to the North American Horizontal Datum of 1983 (NAD83) Horizontal datum. All horizontal coordinates are projected to the California State Plane Zone II coordinate system. River miles presented in this study are based on the March 2002 Sacramento and San Joaquin River Basins Comprehensive study (Comp Study). Project stationing presented in this study is based on the Feather River West Levee Project Stationing defined by SBFCA.

Historical elevation data were converted to NAVD88 from their original legacy reference datum. The method of conversion followed the requirements in ER 1110-2-8160 and the uncertainty in the conversion is accounted for in the study results.

The following generalized conversion is provided to compare NAVD88 elevations provided in this study to previous studies presented in the legacy NGVD29 datum. Expressed as an equation, Elevation (NGVD29) = Elevation (NAVD88) minus 2.40 feet. The conversion between NAVD88 and NGVD29 ranges from 2.3 to 2.4 feet in the study area.

2.0 Study Area

2.1 Watershed

The Sutter Basin study area is situated within the Sacramento River watershed. A map of the Sacramento River watershed is included as Plate 1. The principle watersheds upstream of the study area are the Sacramento River watershed and Feather River watershed. The Sacramento River watershed encompasses the McCloud River, Pit River, and Goose Lake, and Stony Creek. The watershed drains the Sierra Nevada Mountains and Cascade Ranges in the east and the Coast Range and Klamath Mountains in the west. The Feather River watershed encompasses the Yuba River and Bear Rivers. These watersheds drain the eastern slopes of the Sierra Nevada mountain range. The drainage area of the Sacramento River basin upstream of the study area is approximately 12,000 square miles. The drainage area of the Feather River upstream of the study area (including the Yuba and Bear Rivers) is approximately 5,900 square miles.

2.2 Topography

A topographic map of the study area is presented in Plate 2. Elevations within the study area range from 110 ft NAVD88 in the north to 30 ft NAVD88 in the south. The study area has a general slope from northeast to south west. The general slope of the study area is interrupted by two major embankment features which impact hydraulic conveyance within the floodplain. The raised embankment of the Union Pacific Railroad traverses the study area in a north south alignment and the Sutter Bypass east levee traverses the study area in a north south alignment.

2.3 Flood Sources

The Sutter Basin Study area is susceptible to flooding from multiple sources including Butte Basin, Sutter Bypass, Feather River, Cherokee Canal, Wadsworth Canal, and interior sources.

a. Butte Basin. The northwest portion of the study area is within the Butte Basin. The Butte Basin is a natural overflow and flood storage area north west of the Sutter Buttes and east of the Sacramento River. The basin provides approximately 1 million acre-feet of transitory storage at flood stage (DWR, 2010). Excess floodwaters from the Sacramento River enter the Butte Basin via overbank areas along the river and through the Moulton and Colusa weirs. Butte Creek and its tributaries, including Cherokee Canal, also flow into the Butte Basin. Outflow from the Butte Basin is naturally regulated by hydraulic conditions of Butte Slough and floodplain topography at the upstream entrance to the Sutter Bypass. In order to maintain the flood storage capabilities within Butte Basin, California has included regulation of the overflow area in Title 23 of the California Code of Regulations. In general these standards require approval from the board for any encroachments that could reduce or impede flood flows or would reclaim any of the floodplain within the Butte Basin (DWR, 2010).

b. Sutter Bypass. The southwest portions of the study area including the southern portion of Yuba City are susceptible to flooding from the Sutter Bypass. The Sutter Bypass is a leveed flood control channel approximately three quarters of a mile wide, bordered on each side by levees. The bypass is an integral feature of the Sacramento River Flood Control Project's Flood Bypass System. The Sutter Bypass conveys flood waters from the Butte Basin, Sacramento River, and Feather Rivers to the confluence of the Sacramento River and Yolo Bypass at the Fremont Weir.

Downstream of the Feather River the bypass is separated into two conveyance areas by a low levee. The area east of the middle levee conveys flows from the Feather River. This design maintains higher velocities and sediment transport capacity within the Feather River during low flow events while utilizing the large conveyance of the Sutter Bypass during larger events.

The Sutter Bypass also receives minor natural flow and agricultural return flow from Reclamation District 1660 to the west and from Wadsworth Canal and DWR pumping plants 1, 2, and 3 to the east. The Sutter Bypass is described by four hydrologic reaches based on tributary inflows; Butte Slough to Wadsworth Canal, Wadsworth Canal to Tisdale Bypass, Tisdale Bypass to Feather River, Feather River to Sacramento River.

c. Feather River. Nearly the entire study area is susceptible to flooding from the Feather River. The Feather River is a major tributary to the Sacramento River, merging with the Sutter Bypass upstream from the Sacramento River and Fremont Weir. The Yuba and Bear Rivers are major tributaries to the Feather River. Two major flood management reservoirs are located within the Feather River watershed. Oroville Dam and reservoir was completed on the Feather River in 1967. The reservoir has 3,358,000 acre-feet of storage with 750,000 acre-feet of dedicated flood management space. New Bullards Bar dam and reservoir was completed on the Yuba River 1970. The reservoir has 966,000 acre-feet of storage with 170,000 acre-feet of dedicated flood management space. The Feather River is described by four hydrologic reaches based on significant inflows; Thermalito to Honcut Creek, Honcut Creek to Yuba River, Yuba River to Bear River, and Bear River to Sutter Bypass.

d. Cherokee Canal. The northern portion of the study area is susceptible to flooding from Cherokee Canal which is a tributary to Butte Creek and the Butte Basin. The leveed canal was constructed between 1959 and 1960 by USACE under the authorization of the Flood Control Act of 1944. The canal drainage area is 94 square miles and varies in elevation from 70 feet to 2200 feet. The drainage area is bounded by the Feather River watershed to the east and southeast, Butte Creek and its tributaries to the north and west, and by Wadsworth Canal drainage to the south. The design capacity along the Cherokee Canal is 8,500 cubic feet per second (cfs) upstream of the junction with Cottonwood Creek, 11,500 cfs from the junction with Cottonwood Creek to the Biggs Princeton Highway (Afton Road) and 12,500 cfs from the Biggs Princeton Highway to Butte Creek. Based upon the flood frequency analysis at the time of design, the canal was estimated to provide flood protection from a 4% (1/25) ACE event and mitigated sediment transport problems within its watershed.

e. Wadsworth Canal and associated Interceptor canals are potential sources of flooding in the southwest portion of the study area. The Wadsworth Canal system is a feature of the Sacramento River Flood Control Project and consists of leveed channels that carry rainfall and agricultural runoff from 91 square miles of northeast part of Butte and Sutter Counties south to the Sutter Bypass.

(1) <u>West Interceptor Canal</u>. The West Interceptor Canal begins near the town of Sutter and extends 1.8 miles east to Wadsworth Canal. The canal is approximately 30 feet wide and includes a 4 to 5 foot tall Federal Project levee along its right bank. There is no federal levee along the left bank of the canal. The slope of the canal is approximately 25 feet per mile. The purpose of the canal is to intercept rainfall runoff that would otherwise pond against the eastern levee of the Sutter Bypass. The intercepted flow is diverted into the Wadsworth Canal where it is then conveyed to the Sutter Bypass. During extreme floods the peak flow of the canal would be significantly attenuated by the floodplain storage available along the left bank. The canal is also used for irrigation water. The operations and maintenance manual does not list a design flow for the West Interceptor canal.

(2) <u>East Interceptor Canal</u>. The East Interceptor Canal begins near Yuba City and extends 3.1 miles east to the Wadsworth Canal. The canal is approximately 30 foot wide and includes a 4 to 5 foot tall Federal Project levee along its left bank. The purpose of the canal is to intercept rainfall runoff that would otherwise flow southwest and pond against the eastern levee

of the Sutter Bypass. There is no federal levee along the right bank of the canal. The slope of the canal is negligible and the top of levee has a level grade. The intercepted flow is diverted it into the Wadsworth Canal where it is then conveyed to the Sutter Bypass. During extreme floods the peak flow of the canal would be significantly attenuated by the floodplain storage available along the right bank. The canal is also used for irrigation water during the summer irrigation season. The operations and maintenance manual does not list a design flow for the East Interceptor canal.

(3) Wadsworth Canal. Wadsworth Canal begins at the East and West Interceptor Canals near Butte House Road. The canal extends 4.5 miles south to the Sutter Bypass and includes Federal Project Levees along the left and right banks.   The canal is a fairly uniform trapezoidal type channel. The purpose of the canal levee is to collect and convey rainfall runoff and irrigation water from the East and West Interceptor Canals to the Sutter Bypass. The existing Operations and Maintenance Manual for Wadsworth Canal describes a design capacity of 1,500 cfs.

f. Interior Drainage. Runoff from the interior of the study area may result in localized flooding. Interior drainage features include canals and streams tributary to Wadsworth Canal and pumps and culverts along the project levees.

2.4 Stream Gages.

A list of stream gages applicable to the study area is provided in Table 3. The stream gages are operated by the United States Geological Survey (USGS) and California Department of Water resources.   Stream gages are shown on Plate 6.

Table 3 Stream Gages, Sutter Basin Study Area

Gage Name	Area (Sq Mi)	Agency	Gage Number	Period of Record	Type
Bear R Nr Wheatland Ca	292	USGS	11424000	1928-2010	S,Q
Bear River at Pleasant Grove	300	DWR	A06535	1987-2010	S,Q
Butte Creek near Gridley	NA	DWR	A04150	1991-1999	S,Q
Butte Slough at Outfall Gates near Colusa	NA	WDL	A02967	1992-2010	S
Butte Slough near Meridian	NA	WDL	A02972	1981-2010	S,Q
Cherokee Canal nr Gridley	NA	DWR	A00910	1991-1998	S,Q
Cherokee Canal nr Richvale	NA	DWR	A02984	1976-2010	S,Q
Camp Far West Reservoir	NA	DWR	A65105	1998-2010	Q
Colusa Weir Spill to Butte Basin near Colusa	NA	WDL	A02981	1975-2010	S,Q
Deer C Nr Smartville CA	84.6	USGS	11418500	1935-2010	S,Q
Feather River at Nicholaus	5,921	DWR	A05103	1942-2010	S,Q(P)
Feather River at Oroville	3,624	USGS	11407000	1902-2010	S,Q
Feather River at Yuba City	3,974	DWR	A05135	1964-2010	S
Feather River near Gridley	3,676	DWR	A05165	1964-2010	S,Q
Moulton Weir Spill to Butte Basin nr Colusa	NA	DWR	A02986		
Sacramento R at Ord Ferry	12,030	DWR	A02570	1922-2010	S,Q
Sacramento R at Colusa Ca	12,090	USGS	11389500	1941-2010	S,Q
Sacramento R at Verona Ca	21,251	USGS	11425500	1929-2010	S,Q
Sacramento R Blw Wilkins Slough nr Grimes Ca	12,915	USGS	11390500	1931-2010	S,Q
Sacramento River at Butte Slough Outfall Gates	NA	DWR	A02400	1992-2004	S
Sacramento River at Fremont Weir (East)	NA	DWR	A02160	1935-2010	S
Sacramento River at Fremont Weir (West)	NA	DWR	A02170	1934-2010	S
Sacramento River at Knights Landing	14,535	DWR	A02200	1982-2010	S
Sacramento Slough near Karnak	NA	DWR	A02925	1981-2010	S
Sutter Bypass at R.D. 1500 P.P. near Karnak	NA	DWR	A02927	1975-2010	S
Sutter Bypass Channel at Pumping Plant #1	NA	DWR	SB1	2008-2010	S
Sutter Bypass Channel at Pumping Plant #2	NA	DWR	SB2	2008-2010	S
Sutter Bypass Channel at Pumping Plant #3	NA	DWR	SB3	2008-2010	S
Tisdale Weir near Grimes	NA	DWR	A02960	1975-2010	S,Q
Willow Slough near Nicolaus	NA	DWR	A02943	1991-2010	S
Yolo Bypass nr Woodland Ca	NA	USGS	11453000	1939-2011	S,Q
Yuba R blw Englebright Dam near Smartsville	1,108	USGS	11418000	1941-2011	S,Q
Yuba R Nr Marysville CA	1,339	USGS	11421000	1940-2011	S,Q
Wadsworth Canal near Sutter (lower)	96	DWR	A05927	1982-1997	S,Q
Wadsworth Canal near Sutter (upper)	96	DWR	A05929	1976-1997	S,Q
Note: S-Stage, Q-Discharge, NA- Not Available, (Partial Record)					

2.5 Historical Floods.

The Feather River near Oroville gage provides an indicator of large historical floods within the study area. The largest fifteen floods from 1951 to 2010 are presented in Table 4. The magnitudes of historical floods prior to 1967 are not directly comparable to later floods due to significant historical changes in the flood management system. In order to provide a comparison of similar hydrologic conditions, the table includes the estimated unregulated flow for each water year. The ranking of unregulated floods is substantially different than observed flood flows with the 1997 flood being the largest unregulated flood from 1951 to 2010. The following is a description of significant flood events within the study area.

Table 4
Fifteen Largest Annual Maximum Floods
WY1951-WY2010, Feather River at Oroville

Measured				Regulated Peak Flow (CFS)	Unregulated Peak Flow (CFS)	Notes
Annual Ranking	Water Year	Date of Peak	Peak Flow (CFS)			
1	1956	12/23/1955	203,000	150,000	203,000	
2	1963	1/31/1963	191,000		191,000	
3	1997	1/2/1997	161,000	161,000	312,900	
4	1965	12/23/1964	158,000	150,000	260,000	Note 1
5	1960	2/8/1960	135,000		135,000	
6	1986	2/18/1986	134,000	134,000	217,000	
7	1953	1/9/1953	113,000		113,000	
8	1958	2/24/1958	102,000		102,000	
9	1951	11/21/1950	92,100		92,100	
10	1957	2/24/1957	83,100		83,100	
11	1995	3/14/1995	71,700	71,700	134,200	
12	1980	1/15/1980	69,500	69,500	137,600	
13	2006	12/31/2005	65,600	65,600		
14	1952	2/1/1952	59,500		59500	
15	1970	1/25/1970	56,300	56,300	117,700	
Note 1/ Dec 1964 Flood regulated by a partially completed Oroville Dam.						

a. December 1955. The December 1955 flood was the largest peak flow recorded at the Feather River at Oroville gage from 1951 to 2010. Major damage to the study area occurred in December 1955 when the west levee of the Feather River breached near Shanghai Bend killing 38 people. The peak flow measured at the Feather River at Oroville stream gage was 203,000 cfs. This flood occurred prior to construction of Oroville Dam (completed 1967) and New Bullards Bar Dam (completed 1970). Therefore, the flood does not reflect existing hydrologic conditions. A hypothetical flood routing of the 1955 flood is presented in the Oroville Dam and Reservoir water control manual. The flood routing indicates the reservoir would have regulated the peak outflow to 150,000 cfs.

b. December 1964. The December 1964 flood was the fourth largest peak flow recorded at the Feather River at Oroville gage from 1951 to 2010. The main center of precipitation was in the Feather, Yuba, and American River Basins. Rainfall was heaviest on December 22 and 23 1964. Runoff from streams of the Coast Ranges, almost without exception produced peak stages and peak flows that exceeded previous records. Runoff from the Sierra Nevada into the Feather, Yuba and American Rivers surpassed all previous records. This flood occurred during construction of Oroville Dam and was partially regulated to an outflow of 158,000 cfs. A hypothetical flood routing of the 1964 flood is presented in the Oroville Dam and Reservoir water control manual. The flood routing indicates the completed reservoir would have regulated the peak outflow to 150,000 cfs. Had it not been regulated, the peak flow would have been approximately 260,000 cfs which would have exceeded the 1955 flood peak by 57,000 cfs.

b. November 1982 - March1983. Water year 1983 was a result of the “El Niño” weather phenomenon. Northern and Central California experienced flooding incidents from November through March due to numerous storms. In early May, snow water content in the Sierra exceeded

230 percent of normal, and the ensuing runoff resulted in approximately four times the average volume for Central Valley streams. System failures in the Sacramento River Basin were limited to a private levee on the Sacramento River and one failure on Cache Creek.

c. February 1986. Flooding in 1986 resulted from a series of four storms over a 9-day period during February. Rains from the first three storms saturated the ground and produced moderate to heavy runoff before the arrival of the fourth storm. Precipitation at Four Trees in the Feather River Basin set both a 24-hour rainfall record for the Sierra Nevada and the monthly record for any station in the State. During the flood, the left levee of the Yuba River failed just upstream of the Feather River confluence. The communities of Linda and Olivehurst were inundated, resulting in one death, 895 destroyed homes, and 150 destroyed businesses.

d. January 1995. "El Nino" conditions in the Pacific forced major storm systems directly into California during much of the winter and early spring of 1995. The largest storm systems hit California in early January and early March. The major brunt of the January storms hit the Sacramento River Basin and resulted in small stream flooding primarily due to storm drainage system failures.

e. January 1997. December 1996 was one of the wettest Decembers on record. Watersheds in the Sierra Nevada were already saturated by the time three subtropical storms added more than 30 inches of rain in late December 1996 and early January 1997. The third and most severe of these storms lasted from December 31, 1996, through January 2, 1997. Rain in the Sierra Nevada caused record flows that stressed the flood management system to capacity in the Sacramento River Basin and overwhelmed the system in the San Joaquin River Basin. During the flood, the left levee of the Feather River failed near Arboga, killing one person, destroying 180 homes and businesses, and prompting evacuation of about 15,000 people from Linda and Olivehurst. Nearly 50,000 people from Yuba City, Marysville, and surrounding areas were evacuated because of fears of additional levee breaks (USACE, 1998).

f. December 2005 - January 2006. Between 28 December 2005 and 9 January 2006, the State of California experienced a series of severe storms which impacted the levees within the Sacramento District's boundaries. Water rose a second time in April 2006, and remained high in some parts of the system until June. Many rivers and streams within the Sacramento and San Joaquin River systems ran above flood stage during these events, and there were significant erosion and seepage problems with the levees. The State of California Department of Water Resources and/or their maintaining agencies conducted the actual flood fight activities while the U.S. Army Corps of Engineers provided technical assistance to the State.

2.5 Climate Change.

The primary impacts of climate change on Flood Risk Management projects are related to changes in flood frequency estimates, changes in sea level, and their associated uncertainties. The primary climate change consideration within the study area is related to the potential changes in flood frequency estimates. An evaluation of project performance related to changes in climate and flood frequency estimates was conducted using the HEC FDA program and is described in the Hydrology Appendix. Appendix C of EC 1165-2-212 provides a flow chart for evaluating sea level change for a potential project. Based on Step 1 of the flow chart, an evaluation of sea level rise is not required. The study area is approximately 30 feet above mean sea level. Base on sea level trends provided in EC 1165-2-212. Sea level rise would have no impact on the study area up to the year 2100.

3.0 Alternative SB-1 (Without Project Conditions)

3.1 Project Assumptions

a. Levee Design. All existing federal levees are assumed to be maintained to the 1957 design top of levee. The 1957 design top of levee is based on the 1957 design water surface profiles and the minimum freeboard specified in the 1951 Operations and Maintenance Manuals. The 1957 design water surface profile is described on the drawing set, Sacramento River Flood Control Project, California, Levee and Channel Profiles, Drawing File Number 50-10-3334, 15 March 1957. The 1957 design water surface is labeled on the drawing set as the Project Design Flood Plane.

The derivation of the 1957 water surface profiles is described in the memorandum "Levee and Channel Profiles, Sacramento River Flood Control Project" dated 1 July 1957. The 1957 design freeboard is described in the Operations and Maintenance manuals dated 1951. The Sacramento River Flood Control Project adopted multiple existing levees of varying height. The Operations and Maintenance manuals indicates the adopted levee segments met or exceeded the design freeboard. The 1957 design profile and freeboard are described in detail in memorandum on file in the Sacramento District Hydraulic Analysis Section.

b. TRILIA Feather River Setback Levee. The hydraulic analysis of without project conditions includes the setback levee along the left bank of the Feather River constructed by the Three Rivers Levee Improvement Authority (TRILIA).

c. Feather River Star Bend Setback Levee. The without project conditions assumes the levee setback levee on the right bank near Star Bend has not been constructed.

d. Interior Drainage Facilities. The hydraulic analysis assumes all drainage facilities are maintained to their design capacities.

e. Operation and Maintenance. The hydraulic analysis assumes vegetation conditions within the channel will be maintained with similar hydraulic conditions as the existing conditions.

3.2 Hydrology

a. Sutter Bypass, Feather River and Butte Basin. Hydrology for the Sutter Bypass, Feather River, and Butte Basin was based on the Sacramento-San Joaquin Comprehensive study (Comp Study) and Lower Feather River Floodplain mapping study. The Sacramento-San Joaquin Comprehensive study included the entire Sacramento and San Joaquin Valleys. The Lower Feather River Floodplain mapping study was based on the Comprehensive study but included revisions to flow frequencies and hydrographs on the Feather River. Balanced 30-day regulated flow hydrographs developed for 50% (1/2) ACE, 10% (1/10) ACE, 4% (1/25) ACE, 2% (1/50) ACE, 1% (1/100) ACE, 0.5% (1/200) ACE, and 0.2% (1/500) was used in the hydraulic analysis.

The synthetic hydrology investigated unregulated flood frequencies at mainstem and tributary locations throughout the Sacramento Basin. The flood frequency analysis involved evaluations of long term historical records at the stream gages. The unregulated flow frequency statistics and period of record for the Sacramento River at Bend Bridge, Feather River at Oroville, and Feather River at Shanghai Bend were used to estimate hydrologic uncertainty in the Sutter Basin Feasibility Study. The adopted statistics and period of record for the unregulated conditions are provided in Tables 5, 6, and 7.

Table 5
Rain Flood Frequency, Sacramento River at Ord Ferry
Unregulated Conditions

Flood Duration	Adopted Log Mean	Adopted Log Standard Deviation	Adopted Log Skew	Record (Years)	
				Years Evaluated	Years Used
1-Day	5.009	0.281	0.0	1922-1997 (1977 censored)	75
3-Day	4.939	0.281	0.0	1922-1997 (1977 censored)	75
5-Day	4.866	0.279	-0.1	1922-1997 (1977 censored)	75
10-Day	4.809	0.278	-0.1	1922-1997 (1977 censored)	75
15-Day	4.680	0.267	-0.3	1922-1997 (1977 censored)	75
30-Day	4.562	0.258	-0.3	1922-1997 (1977 censored)	75
1977 censored as a low outlier					

Table 6
Rain Flood Frequency, Feather River at Oroville
Unregulated Conditions

Flood Duration	Adopted Log Mean	Adopted Log Standard Deviation	Adopted Log Skew	Record (Years)	
				Years Evaluated	Years Used
Peak	4.743	0.390	-0.2	11 years	11
1-Day	4.639	0.390	-0.2	1901-1997	97
3-Day	4.533	0.392	-0.2	1901-1997	97
7-Day	4.387	0.377	-0.3	1901-1997	97
15-Day	4.250	0.351	-0.4	1901-1997	97
30-Day	4.129	0.326	-0.4	1901-1997	97

Table 7
Rain Flood Frequency, Feather River at Shanghai Bend
Unregulated Conditions

Flood Duration	Adopted Log Mean	Adopted Log Standard Deviation	Adopted Log Skew	Record (Years)	
				Years Evaluated	Years Used
Peak	4.951	0.402	-0.3	1904-1997	94
1-Day	4.857	0.402	-0.3	1904-1997	94
3-Day	4.733	0.404	-0.3	1904-1997	94
7-Day	4.582	0.387	-0.3	1904-1997	94
15-Day	4.443	0.363	-0.4	1904-1997	94
30-Day	4.321	0.340	-0.4	1904-1997	94

Seven storm centerings were formulated in the Comp Study to represent the many different possibilities of aerial storm distributions and antecedent watershed conditions. For each centering, synthetic 30-day natural flow hydrographs were computed at locations throughout the Central Valley. Typically, each tributary basin contained one hydrograph location. Many of these sites were inflow points to major flood management projects (i.e., Feather River at Oroville Dam). These natural flow hydrographs represent flood time series produced by a wholly unimpaired drainage area. The unimpaired hydrographs do not reflect the influence of headwater reservoirs. The hydrographs were balanced so the average flow for all durations matched the given frequency. For example, the peak, 1-day, 3-day, 5-day, 15-day, and 30-day volumes match the given frequency event.

A 3-step process was required to conduct simulations of reservoir regulations for each storm centering. To begin the sequence, the headwaters reservoirs upstream of the flood control reservoirs were simulated. Then, using the resulting storage time series for select headwater facilities, top of conservation storage for those flood damage reduction projects with established credit space agreements were computed. Next, using the results of the headwater simulations and the computed top of conservation series, the lower basin reservoir models were simulated, thereby completing the reservoir simulation procedure.

A regulated set of hydrographs was obtained from “hand off” points in the lower basin reservoir simulation model. These hydrographs were used as the input to the HEC-RAS unsteady flow models in the feasibility study. A review of the seven storm centerings found that peak stages along the Sutter Bypass and Feather Rivers are generated by either the Sacramento River storm centering or Shanghai Bend storm centering. Therefore, these are the only two centerings modeled in the feasibility study. In order to determine the peak stage for a given frequency event both storm centerings are modeled. The set of unregulated flow hydrographs provided at hydraulic model boundary locations shown on Plate 6 and listed in Table 8.

Table 8 Regulated Boundary Condition Hydrographs

Model Boundary	Name
1	BEAR RIV BLW CAMP FAR WEST
2	BEST SLOUGH AT FORTY MILE ROAD
3	BUTTE SLOUGH AT WEST BUTTE ROAD
4	CACHE C A YOLO CA (#11452500)
5	YUBA - DRY CREEK AT HWY 20
6	BEAR RIVER - DRY CREEK AT JASPER LN
7	FEATHER RIVER AT OROVILLE (#11407000)
8	HONCUT CREEK AT HWY 70
9	JACK SIMMERLY AT WOODRUFF LN
10	KLRC AT KNIGHTS LANDING
11	NATOMAS CROSS CANAL AT GARDEN HWY
12	SACRAMENTO R A COLUSA CA (#11389500)
13	SACRAMENTO R A VERONA CA (#11425500)
14	UP INTERCEPT SA REEDS
15	WADSWORTH CANAL AT HWY 20
16	YANKEE SLOUGH AT SWETZER ROAD
17	YOLO BYPASS NR WOODLAND CA (#11453000)
18	YUBA RIVER AT RS 13.84

b. Wadsworth Canal. Flow frequency analysis for Wadsworth Canal is described in the Feasibility Study Hydrology Appendix. Wadsworth canal is an unregulated stream. The Wadsworth Canal unregulated frequency curve was developed from graphical frequency analysis of gage records at Wadsworth Canal near Sutter (DWR stream gage A05929) following Bulletin 17B guidelines. The analysis was based on mean daily flows from 1939 to 1996. The years 1976 and 1977 were screened as low outliers and were not used in the analysis. The peak flow frequency was estimated from the mean daily flows. A 37 year equivalent period of record is recommended for the peak flow frequency to account for the additional hydrologic uncertainty. A table of peak unregulated flows for Wadsworth Canal is provided in Table 9. These flows represent a storm centered over the Wadsworth canal drainage area.

Table 9
Flow Frequency, DWR Gage Wadsworth Canal near Sutter

Peak Discharge by ACE (cfs)						
50% (1/2)	**10% (1/10)**	**4% (1/25)**	**2% (1/50)**	**1% (1/100)**	**0.5% (1/200)**	**0.2% (1/500)**
820	2,250	3,200	4,000	4,830	5,750	7,070

The water surface profile of Wadsworth Canal is influenced by inflow from the East and West Interceptor Canals and the coincident downstream stage in the Sutter Bypass. Inflow from Wadsworth canal is approximately 1% of the flow in the Sutter Bypass. Therefore, inflow from Wadsworth Canal has negligible impact on stages in the Sutter Bypass during the flood season. Stage and flow frequency estimates for the Sutter Bypass were obtained from the Sutter Bypass and Feather River model. Peak flow and stage frequency estimates are provided in Tables 10 and 11 respectively.

Table 10
Flow Frequency, Sutter Bypass below Wadsworth Canal

Scenario	Peak Flow (FT-NAVD88)						
	50% (1/2)	**10% (1/10)**	**4% (1/25)**	**2% (1/50)**	**1% (1/100)**	**0.5% (1/200)**	**0.2% (1/500)**
A. No Overtopping or Failure	57,600	102,800	127,200	156,100	185,400	229,500	328,900
B. Overtopping without Failure	Same	Same	Same	Same	Same	228,300	255,000
HEC-RAS model, Sutter Bypass, Wads-Tisdale, Section 84.14							

Table 11
Stage Frequency, Sutter Bypass at Wadsworth Canal Confluence

Scenario	Peak Stage (FT-NAVD88)						
	50% (1/2)	**10% (1/10)**	**4% (1/25)**	**2% (1/50)**	**1% (1/100)**	**0.5% (1/200)**	**0.2% (1/500)**
A. No Overtopping or Failure	46.87	50.64	52.75	54.42	56.19	58.53	63.21
B. Overtopping without Failure	Same	Same	Same	Same	Same	58.45	59.82
HEC-RAS model, Sutter Bypass, Wads-Tisdale, Section 84.14							

c. Cherokee Canal. Hydrologic analysis conducted for Cherokee Canal is described in the report “Sutter, Basin California, General Investigation Feasibility Study, Cherokee Canal Hydrology Appendix, Cottonwood Creek to Afton Road Butte County, California”, August 2010. Flood frequency curves and a suite of 30 day balanced hydrographs were developed for the Cherokee Canal near Richvale Gage (DWR stream gage A02984). The frequency analysis was conducted using Bulletin 17b methods based on 46 years of record from 1961 to 2006. Flood frequency statistics for the Cherokee Canal near Richvale Gage are provided in Table 12. A table of discharges by frequency and duration is provided in Table 13.

Table 12
Flood Frequency Statistics, DWR Gage Cherokee Canal near Richvale

Flood Duration	Log Mean	Log Standard Deviation	Log Skew (Adopted)	Record (Years)	
				Years Evaluated	Years Used
Peak	3.7484	0.2241	-0.70	46	46
1-Day	3.4576	0.2241	-0.70	46	46
3-Day	3.2656	0.2241	-0.70	46	46
5-Day	3.1618	0.2241	-0.70	46	46
10-Day	3.0052	0.2241	-0.70	46	46
15-Day	2.9130	0.2241	-0.70	46	46
30-Day	2.7525	0.2241	-0.70	46	46

Table 13
Flood Frequency, DWR Gage Cherokee Canal near Richvale

Flood Duration	Duration Average Discharge by ACE (CFS)						
	50% ACE	10% ACE	4% ACE	2% ACE	1% ACE	0.5% ACE	0.2% ACE
Peak	5,900	10,300	12,100	13,200	14,300	15,200	16,300
1-Day	3,040	5,280	6,190	6,870	7,310	7,780	8,340
3-Day	1,960	3,390	3,980	4,360	4,700	5,000	5,360
5-Day	1,540	2,670	3,130	3,430	3,700	3,940	4,220
10-Day	1,070	1,860	2,180	2,390	2,580	2,750	2,950
15-Day	870	1,510	1,770	1,940	2,090	2,220	2,380
30-Day	600	1,040	1,220	1,340	1,440	1,540	1,650

Balanced 30-day hydrographs were developed for 50% (1/2) ACE, 10% (1/10) ACE, 4% (1/25) ACE, 2% (1/50) ACE, 1% (1/100) ACE, 0.5% (1/200) ACE, and 0.2% (1/500) ACE events. The hydrographs were developed using the same methodology as described in the Comp Study. The 5-day flood pattern for the synthetic hydrographs was based on the 30 December 2005 to 4 January 2006 flood. The 30-day hydrograph was then constructed from 6 waves, each 5 days in duration. The highest wave volume is distributed into the fourth, or main, wave. The second and third highest volumes precede and follow the main wave, respectively. The fourth highest volume is distributed into the 2nd wave, and the 5th highest is distributed into the final of the 6 waves. The 6th and smallest wave volume is distributed into the 1st wave of the series. The shape of each wave is identical and the magnitude is determined by the total volume that the wave must carry.

d. Interior Drainage. An interior drainage analysis was performed by Peterson-Brustad Incorporated (PBI) for the Sutter Butte Flood Control Agency (SBFCA). The interior drainage analysis evaluated rainfall runoff and flood depths for 2% (1/50) ACE, 1% (1/100) ACE, 0.5% (1/200) ACE flood events. Storm events with 24-hour and 96 hour durations were evaluated.

The analysis utilized an HEC-HMS model to compute sub basin runoff and a FLO-2D two dimensional hydraulic model to route the runoff through the study area. A total of 16 drainage basins covering approximately 340 square miles were identified within the interior drainage boundary. The drainage basins were further divided into a total of 77 sub basins. The model included ten storm water pump stations that pump drainage water into the Feather River or Sutter Bypass. The FLO-2D model uses a 1,000-foot by1,000-foot grid size and includes the main drainage channels throughout the study area as channel elements. The resulting interior drainage maps were reviewed and adopted for use in this study. The maps are further described in the analysis of alternatives below.

3.3 Hydraulic Models

Without project conditions were evaluated using an uncoupled 1-d and 2-d modeling approach that is standard procedure on multiple studies within the Sacramento District. River stages and profiles were simulated using a 1-dimensional HEC-RAS model because RAS incorporates more detailed hydraulic capabilities for channel flow. Levee breaches were simulated using the same HEC-RAS model because the levee breach capabilities are more detailed in RAS than FLO-2D. These breaches were then transferred to a 2-dimensional FLO-2D model of the floodplain. The FLO-2D model has more detailed capabilities than HEC-RAS for simulating the distribution of the breach hydrographs on the floodplain. This process leverages the most robust capabilities of both models. Ideally, this would be conducted using a coupled 1-d and 2-d model but that capability is not readily available with standard models used by the district.

Five separate hydraulic models that were adapted from existing hydraulic models utilized for studies within the Sacramento Valley. These existing models were reviewed and determined to be adequate for the Sutter Basin Feasibility Studyl analysis. Water surface profiles for Sutter Bypass and Feather River were computed using an HEC-RAS unsteady one-dimensional flow model of the Sacramento River system. Water surface profiles for Wadsworth Canal were computed using an HEC-RAS steady one-dimensional flow model. Water surface profiles for Cherokee Canal were computed using an HEC-RAS unsteady one-dimensional flow model. Water surface elevations for Butte Basin were based on the UNET unsteady model results obtained from the Comp Study. Inundation depths from levee breach simulations were evaluated using a FLO-2D 2-dimensional unsteady flow model of the study area.

Three types of hydraulic model computer programs were used for this analysis. The computer model HEC-RAS calculates steady or unsteady gradually varied flow in natural and manmade channels by performing step-backwater calculations of the 1-D flow energy equation through a series of input geometric cross-sections with empirically defined hydraulic roughness coefficients. The computer model, UNET is a predecessor to HEC-RAS and has similar functionality and assumptions. The computer model FLO-2D is a 2-dimensional, dynamic flood routing model that simulates movement of water across the ground surface while reporting volume conservation. It numerically routes flood hydrographs over a system of grid elements, and predicts the area of inundation and floodwave attenuation.

a. Sutter Bypass and Feather River. Water surface profiles for Sutter Bypass and Feather River were computed using an HEC-RAS unsteady one-dimensional flow model of the Sacramento River system. A map of the HEC-RAS hydraulic model domain showing cross sections and hydrograph boundary locations is provided as Plate 6.

(1) <u>Cross Sections</u>. The model contains a total of 1,382 cross sections. The cross sections are spaced at roughly ¼-mile intervals along the river reaches. Cross section geometry data were obtained from the 1999 Sacramento-San Joaquin Comprehensive Study (NAVD88 datum update). The hydraulic model geometry includes the sloped levee face except at star bend and Three River Levee Improvement Authority (TRLIA) setbacks on the Feather River. This is an appropriate assumption because the sloped portion of the levee is an extremely small fraction of the overall cross sectional area.

(2) <u>Storage Areas</u>. The model contains a total of 53 storage areas throughout the domain.

(3) <u>Bridges and Inline Structures</u>. The model contains a total of 33 bridges, 3 inline structures and 2 major weir diversions (Fremont and Tisdale). The Highway 99 Bridge was modified over the period of the feasibility study. The model represents the widened bridge.

(4) Lateral Stuctures (Levees). The HEC-RAS model utilizes the lateral weir option to simulate overtopping of the levee crest. The structures were manually coded into each HEC-RAS cross section based upon Top of Levee (TOL) elevation data from the USACE National Levee Database (NLDB) survey data. The lateral structure outflow is linked to the storage areas described above.

(5) Blocked Obstructions. Blocked obstructions were used throughout the model to eliminate the cross section area on the landward side of the levee. The landward areas are modeled as storage areas and lateral weirs along the crest of the levee control the flow over and into and out of the storage areas. The blocked obstructions are needed because the cross sections extend approximately 100 feet landward of the levee and this is not a conveyance area under this approach. The levee card is not suitable in this case because the conveyance area on the landward side of the cross section would become conveyance area once overtopped. The heights of the blocked obstructions were made sufficiently high to contain a 0.2% ACE flood event.

(6) Ineffective Flow Areas. Ineffective flow areas were incorporated into the model to simulate areas where water is stored, but is not active conveyance area.

(7) Manning's Roughness Values. Manning's n-values were selected based on model calibration to high water marks collected during the January 1997 and December 2005 - January 2006 flood events. Boundary condition inflows for the model calibration were based on DWR and USGS stream gage records. Manning's roughness values range from 0.031 to 0.07 in the main channel and 0.05 to 0.10 in the overbanks. The model calibration is described below.

(8) Upstream Boundary Conditions. Upstream boundary conditions are a set of regulated flow hydrographs. The boundary locations are shown on Plate 6 and listed in Table 3.

(9) Downstream Boundary Conditions. The PBI Sutter Basin model includes two downstream boundary conditions; 1) the Sacramento River at Verona and 2) the Yolo Bypass near Woodland. Both boundary conditions consist of rating curves developed from stream gage data.

A stage-discharge rating curve was developed for the downstream boundary at the Sacramento River at Verona gage. The current USGS rating at the gage was found to be at the low end of historical data. The USGS stage-discharge rating was modified to reflect the average conditions expected throughout the life of the project. The resulting curve is provided as Plate 7.

A stage-discharge curve was developed for the Yolo Bypass near Woodland Gage. The published USGS Yolo Bypass near Woodland gage rating curve could not be used for the boundary condition because it incorporates an adjustment for Sacramento Weir inflow into the Yolo Bypass. The gage, however, is located upstream of the confluence with the Sacramento Bypass. As a result, the USGS rating curve does not represent the stage-flow relationship at the gage. The curve used for the feasibility study was developed by plotting historical discharge measurements and comparing to modeled profiles of the Yolo Bypass. The resulting curve is provided as Plate 8.

(10) Model Calibration. The model was calibrated to two historic flood events that occurred in January 1997 and December 2005 - January 2006. Calibration efforts were specifically focused on the Feather River, Sutter Bypass, and Wadsworth Canal. Detailed calibration for all of the other rivers and storage areas within the HEC-RAS model was considered outside of the scope of this study.

The differences in the physical configuration of the Feather River between 1997 and 2006 (such as the Shanghai Bend Setback Levee completed in 1999) were taken into account in the calibration process. In addition, due to the fact that both the 2006 and 1997 flood events occurred before the construction of the TRLIA setback levees, the calibration was performed with a HEC-RAS geometry file that does not include the setback levees.

The January 1997 flood event was considered the best flood event to use for calibration due to its size and the quantity of measured data. However, three major levee breaches occurred during the 1997 flood event which introduced significant uncertainty in flow estimates throughout the system. The storm that occurred from December 2005 to January 2006 was smaller in size compared to the 1997 event, but it was large enough to produce overbank flows and reliable measured data throughout the river network with no levee failures.

Manning's n-values were adjusted to duplicate stages for the 2006 flood event. The 1997 flood event was then simulated and adjustments were made to achieve a compromise in modeled versus observed stages for the two calibration events. For the 1997 event the difference between modeled and observed stages ranged from -0.30 feet to +1.92 feet at the 12 stream gages. The greatest deviation between observed stage and the modeled stage occurred at the Sutter Bypass pumping Plant 1 gage.

For the 2006 event the difference between modeled versus observed stages ranged from -0.46 feet to +1.03 feet at the 12 stream gages. The greatest deviation between modeled and observed stages occurred at the Feather River at Yuba City gage. The model overestimated the stage by 1.03 feet. The calibration is described in the PBI report, Design Water Surface Profiles for the Feather River West Levee Project, 26 July 2012.

(11) Stage Uncertainty. The total SD of stage uncertainty was computed at 11 index points on the Feather River and Sutter Bypass. The total SD was found to range from 1.2 feet to 1.7 feet. A SD of 1.5 feet is recommended for all reaches of the Sutter Bypass and Feather River.

Stage uncertainty was estimated following methods described in EM-1110-2-1619. The total stage uncertainty was estimated from natural, model, and sedimentation uncertainty. The following provides a summary of the stage uncertainty analysis. A detailed description of the stage uncertainty analysis is provided in the Sutter Basin Feasibility Study Hydraulics Report prepared by Peterson Brustad Inc. (SBFCA, 2012). The standard deviation (SD) of total stage uncertainty was calculated using the following equations modified from EM1110-2-1619.

$$\mathrm{SD_{total}} = \sqrt{\mathrm{SD^2_{natural}} + \mathrm{SD^2_{model}} + \mathrm{SD^2_{sedimentation}}}$$

$$\mathrm{SD_{model}} = \sqrt{\mathrm{SD^2_{topo}} + \mathrm{SD^2_{n-value}}}$$

The natural uncertainty, *SDnatural*, is the uncertainty of the stage-discharge relationship caused by the natural variation in the physical characteristics of the stream and errors that occur in the stage and discharge measurements.The SD of natural uncertainty is 0.70 feet for the Feather River and 0.55 ft for the Sutter Bypass. The SD for natural uncertainty was based on a review of stage discharge measurements at the DWR stream gage Butte Slough near Meridian (A02972) and USGS gage Sacramento River near Verona (11425500).

The uncertainty in hydraulic model results is highly correlated to the uncertainty in the topographic data used to represent the geometric characteristics of the river reaches. The SD for topographic uncertainty is estimated to be 0.48 ft. This uncertainty value was based on the description of the topographic survey data provided in the Aryes Final Topographic Survey Report (AYRES, 2003)

The SD associated with Manning's roughness was estimated at 11 locations throughout the model. The standard deviation was found to range from 0.78 feet to 1.25 feet. The values were estimated by computing water surface profiles with roughness values increased and decreased by 20 percent.

The SD associated with sedimentation accounts for the sensitivity of the computed water surface profiles to future sediment deposition or scour. A SD of 0.75 feet was estimated for all reaches based on a review of sedimentation reports.

b. Wadsworth Canal. Water surface profiles for Wadsworth Canal were computed using an HEC-RAS steady one-dimensional flow model. A map of the HEC-RAS hydraulic model domain showing cross sections and hydrograph boundary locations is provided as Plate 9. The hydraulic model extends 4.5 miles from the East and West Interceptor Channel to the Sutter Bypass.

(1) Cross Sections. The model contains 36 cross sections from the East and West Interceptor Channels to the Sutter Bypass. Cross section geometry data were obtained from the 1999 Sacramento-San Joaquin Comprehensive Study (NAVD88 datum update). The underwater portion of each cross section was adjusted to reflect recent NAVD88 ground surveyed bathymetric cross section data obtained by the State of California Department of Water Resources in 2010 (DWR, 2011).

(2) Storage Areas. The model is a steady state model used to model profiles. Therefore, the model does not include storage areas.

(3) Bridges and Inline Structures. Bridges and inline structures were coded into the model from field sketches obtained during the 1999 Sacramento-San Joaquin Comprehensive

Study and the State of California Department of Water Resources Central Valley Floodplain Evaluations and Delineation (CVFED) mapping. The five bridges within the model reach are Butte House Road, South-Butte Road, Sutter Bike Trail (old railroad bridge), Colusa Highway (State Highway 20), and Franklin Road.

Topographic and NLDB data in the vicinity of the Sutter Bike Trail bridge indicated a dip in the left and right bank levee profile. A review of photographs indicated the top of levee should tie to the concrete wing walls and railing. The DWR Sutter Yard Field Superintendent indicated this location would be sandbagged during a flood event (DWR, 2013). Therefore, the top of levee was coded into the model at the top of the wing wall elevation.

Weir number 4 located just upstream from South-Butte Road was coded into the model as an inline structure assuming the flash boards were removed. The DWR Sutter Yard Field Superintendent indicated the flash boards would not be in place during the flood season (DWR, 2013).

(4) <u>Levees.</u> The levee crest elevation was specified for each cross section. The top of levee elevation was obtained from the NAVD88 National Levee Database (NLDB) ground survey conducted in 2007-2008.

(5) <u>Blocked Obstructions</u>. Blocked obstructions were used throughout the model to eliminate the cross section area on the landward side of the levee. The landward areas are modeled as storage areas and lateral weirs along the crest of the levee control the flow over and into and out of the storage areas. The blocked obstructions are needed because the cross sections extend approximately 100 feet landward of the levee and this is not a conveyance area under this approach. The levee card is not suitable in this case because the conveyance area on the landward side of the cross section would become conveyance area once overtopped. The heights of the blocked obstructions were made sufficiently high to contain a 0.2% (1/500) ACE flood event.

(6) <u>Ineffective Flow Areas</u>. Ineffective flow areas were incorporated into the model to simulate areas where water is stored, but is not active conveyance area.

(7) <u>Manning’s Roughness Values</u>. Manning’s roughness values were estimated to be 0.035 for the Wadsworth Canal reach. This value was based on a comparison of channel conditions to photographs in Chow, 1959.

(8) <u>Upstream Boundary Conditions</u>. Model boundary conditions for stage and flow are described in the Model Simulations and Results section.

(9) <u>Downstream Boundary Conditions</u>. Model boundary conditions for stage and flow are described in the Model Simulations and Results section of this report.

(10) <u>Model Calibration</u>. The model was not calibrated due to lack of measured data. Selection of Manning’s roughness values are described above.

(11) Stage Uncertainty. The total SD was found to vary between 1.5 feet and 1.6 feet throughout the reach. Stage uncertainty was estimated following methods described in EM-1110-2-1619. The total stage uncertainty was estimated from natural, model, sedimentation uncertainty, and coincident flow uncertainty. The SD of stage uncertainty releated to natural, model, and sedimentation uncertainty was assumed to be the same as the Sutter Bypass (1.5 feet) because water surface profiles in Wadsworth Canal are highly correlated to the stage in the Sutter Bypass.

Additional stage uncertainty was included to account for uncertainty in coincident flow conditions. The maximum stage uncertainty related to coincident flow conditions is assumed to be the difference between the maximum and minimum coincident flow extremes. Equation 5-7 of EM 1110-2-1619 was used to compute the standard deviation of stage uncertainty as 1/4 of the difference between the upper and lower bounds. The stage uncertainty associated with coincident flow varies throughout the reach and is the largest (0.6 feet) near Sutter Butte Road (Comp Study River Mile 3.32). The standard deviation (SD) of total stage uncertainty was calculated using the following equation provided in EM1110-2-1619.

$$\mathrm{SD}_{\mathrm{total}} = \sqrt{\mathrm{SD}^2_{\mathrm{natural}} + \mathrm{SD}^2_{\mathrm{model}} + \mathrm{SD}^2_{\mathrm{sedimentation}} + \mathrm{SD}^2_{\mathrm{coincident\ flow}}}$$

c. Cherokee Canal. Water surface profiles for Cherokee Canal were computed using an HEC-RAS unsteady one-dimensional flow model. A map of the HEC-RAS hydraulic model domain showing cross sections and hydrograph boundary locations is provided as Plate 10. Model geometry was obtained from an existing California Department of Water Resources model developed in 2006. The model reach extends 9 miles from Nelson Road downstream to Highway 162.

(1) Cross Sections. The Cherokee Canal HEC-RAS hydraulic model contains a total of 153 cross sections. The cross sections are spaced at roughly 400-ft intervals. Cross sections are also coded at the upstream and downstream face of each bridge crossing.

The topography included in the DWR 2006 model (excluding the cross sections imported from the URS 2003 model) was obtained from field surveys completed in June and August of 2006 by DWR. Supplemental field surveys were completed by PBI in June and October of 2009 in order to add 4 cross sections downstream of the Highway 162 Bridge.

(2) Storage Areas. The model contains no storage areas.

(3) Bridges and Inline Structures. The model includes 4 bridges, Nelson-Shippee Road, Richvale Road, Union Pacific Railroad, and Highway 162. All of the bridges geometry data within the model were obtained from the 2006 DWR model and reviewed for reasonableness. The bridge deck elevation for all bridges was surveyed to verify the vertical datum was NAVD88.

(4) Lateral Stuctures (Levees). The HEC-RAS model utilizes the lateral weir option to simulate overtopping of the levee crest. The structures were manually coded into each HEC-RAS cross section based upon Top of Levee (TOL) elevation data from the USACE NLDB survey data described above. Lateral structures were not coded in for the reach upstream of Nelson-Shippee Road in order to ensure that all inflows enter the study area. Lateral structure lengths were coded in to be no greater than 1 mile.

(5) Blocked Obstructions. Blocked obstructions were used throughout the model to eliminate the cross section area on the landward side of the levee. The landward areas are modeled as storage areas and lateral weirs along the crest of the levee control the flow over and into and out of the storage areas. The blocked obstructions are needed because the cross sections extend approximately 100 feet landward of the levee and this is not a conveyance area under this approach. The levee card is not suitable in this case because the conveyance area on the landward side of the cross section would become conveyance area once overtopped. The heights of the blocked obstructions were made sufficiently high to contain a 0.2% (1/500) ACE flood event.

(6) Ineffective Flow Areas. The model contains no ineffective flow areas. The ineffective flow areas upstream of the Nelson-Shippee Road Bridge (outside of the study area) were eliminated from the base DWR model in order to stabilize the unsteady flow calculations.

(7) Manning's Roughness Values. The Manning's n-values for the main channel range from 0.033 to 0.059. The Manning's n-values for the channel overbanks range from 0.037 to 0.088. Manning's n-values were selected based on model calibration to high water marks collected during the December 2005 - January 2006 flood events. Boundary condition inflows for the model calibration were based on DWR stream gage records.

(8) Upstream Boundary Conditions. The hydrograph provided for Cherokee Canal was based on stream records below the Cottonwood creek tributary. However, the model extends upstream of Cottonwood creek. The hydrograph was divided and 75% was applied at the upstream end of the model at Nelson Road and 25% was applied at the Cottonwood Creek confluence. This apportionment was based upon the percent differences in the design capacities of the Cherokee Canal upstream and downstream of the Cottonwood Creek confluence. No detailed hydrologic analysis was completed since these sections were outside of the focus study area. A 1-hour time delay was applied to the inflow hydrograph at Cottonwood Creek in order to synchronize the combined peak flows.

(9) Downstream Boundary Conditions. A normal depth (friction slope) boundary condition of 0.00068 was utilized for the model. The friction slope was estimated from the surveyed high water mark elevations in the downstream one-mile of the model.

(10) Model Calibration. Manning's n-values were selected based on model calibration to high water marks collected during the December 2005 - January 2006 flood events. Boundary condition inflows for the model calibration were based on DWR stream gage records. Manning's n-values were adjusted (within reason) to duplicate stages for the event. The calibrated water surface profile was found on average to be within 0.3-ft of known HWM's.

There are two instances within the study focus area where the difference between the known HWM's and the modeled water surface was greater than 0.5-feet. However, considering uncertainty in high water mark data collection, these were considered outliers. A detailed description of the stage model calibration is provided in the Sutter Basin Feasibility Study Hydraulics Report prepared by Peterson Brustad Inc. (SBFCA, 2012).

(11) Stage Uncertainty. The total SD of stage uncertainty was computed at two index points on the Cherokee Canal and a SD of 1.5 feet is recommended. Stage uncertainty was estimated following methods described in EM-1110-2-1619. The total stage uncertainty was estimated from natural, model, sedimentation, and bridge debris loading uncertainty. The following provides a summary of the stage uncertainty analysis. A detailed description of the stage uncertainty analysis is provided in the Sutter Basin Feasibility Study Hydraulics Report prepared by Peterson Brustad Inc. (SBFCA, 2012). The standard deviation (SD) of total stage uncertainty was calculated using the following equation provided in EM1110-2-1619.

$$\mathrm{SD_{total}} = \sqrt{\mathrm{SD^2_{natural}} + \mathrm{SD^2_{model}} + \mathrm{SD^2_{sedimentation}} + \mathrm{SD^2_{bridge\ debris}}}$$

$$\mathrm{SD_{model}} = \sqrt{\mathrm{SD^2_{topo}} + \mathrm{SD^2_{n-value}}}$$

The natural uncertainty, *Snatural*, is the uncertainty of the stage-discharge relationship caused by the natural variation in the physical characteristics of the stream and errors that occur in the stage and discharge measurements. The SD of natural uncertainty is 0.48 feet. The SD for natural uncertainty was based on a review of stage discharge measurements at the DWR stream gage Cherokee Canal nr Richvale (A02984).

The uncertainty in hydraulic model results is highly correlated to the uncertainty in the topographic data used to represent the geometric characteristics of the river reaches. The SD for topographic uncertainty was assumed to be negligible because the cross sections were ground surveyed.

The SD associated with Manning's roughness was estimated at two locations throughout the model. The standard deviation was found to range from 0.73 feet to 0.78 feet. The values were estimated by computing water surface profiles with roughness values increased and decreased by 20 percent.

The SD associated with sedimentation accounts for the sensitivity of the computed water surface profiles to future sediment deposition or scour. A SD of 0.75 feet was estimated for all reaches based on a review of sedimentation reports.

The SD associated bridge debris loading was estimated at two locations throughout the model. The values were estimated by computing water surface profiles with bridge pier widths increased 2 feet. The standard deviation was found to range from 0.02 feet to 0.03 feet.

d. Butte Basin. Water surface elevations within the Butte Basin were obtained from the Sacramento San Joaquin Comprehensive Study UNET model DSS files. All stage data provided in the Comprehensive Study were based on the NGVD29 datum. These data were converted to the NAVD88 vertical datum using a topographic datum conversion surface developed specifically for converting Comp Study topographic data to NAVD88. Model geometry, details and assumptions are described in the Sacramento San Joaquin Comprehensive Study report.

(1) Boundary Conditions. Hydrologic inputs to the comp study UNET hydraulic model consisted of a set of 30-day regulated flow hydrographs for all inflow boundary locations. Sets of boundary condition hydrographs were provided for each of seven ACE events. Storm centering scenarios were provided for each ACE event to determine the maximum water surface elevations within the river channels. The development of regulated flow hydrographs is described in detail in the hydrology appendix.

(2) Model Calibration. The UNET model of the Sacramento River Basin was calibrated to the 1997 flood during the comp study. Inflow hydrographs to the model were created using 1997 flood gage information from major tributaries and flood control structures. Model result hydrographs were compared to gage records and peak stage data where available. The UNET model parameters for Manning's n, weir coefficients, and levee breaches were then adjusted as needed in an iterative procedure to modify the model results to more closely match the calibration data.

(3) Stage Uncertainty. Stage uncertainty was estimated following methods described in EM-1110-2-1619. The total stage uncertainty was estimated from natural, model, sedimentation uncertainty, and coincident flow uncertainty. The SD of stage uncertainty releated to natural, model, and sedimentation uncertainty was assumed to be the same as the Sutter Bypass and Feather River model described above (1.5 feet) because the comp study UNET model data sources and assumptions are nearly identical to the HEC-RAS model.

e. FLO-2D Model. A FLO-2D model was utilized to evaluate water surface elevations resulting from levee breaches within the study area. A detailed description of the model is provided in the report- Sutter Basin Feasiblity Study, Hydraulics Report prepared by Peterson Brustad, Inc. 14 December 2012. A map of the model domain is provided in Plate 11.

(1) Computational Domain**.** The valid computational domain is defined as the Sutter Basin Feasibility study area. The model's domain extends beyond the valid computational domain in order to establish model boundary conditions. All results outside the valid domain were truncated from the results.

(2) Grid Elements**.** A 1,000-ft grid size was selected in order to keep the number of grid elements down to a workable number and to avoid long model run times. The Comp Study and USGS data were used to develop the FLO-2D grid cell elevations, with the Comp Study topography comprising approximately 55% of the FLO-2D grid. The USGS topography is utilized for the areas of the model which Comp Study topography did not cover. Since both the Comp Study and USGS data is based upon NGVD29 datum, the FLO-2D grid cell elevations were converted to NAVD88. This was the best available topographic data at the time of model development. More detailed Lidar topography became available after model simulations had been completed. The more detailed topography was compared against this data set. Although the

uncertainty in absolute elevations may be on the order of 1 to 2 feet, this would have little influence on economic damages which are based on depth.

(3) Channel Elements**.** Two channels were added to the 2009 Sutter Basin FLO-2D model; the Wadsworth Interceptor Canal Unit 1 (West Canal) and Interceptor Canal Unit 2 (East Canal). The channels were included in order to simulate the collection and drainage of runoff out of the basin via the Wadsworth Canal. The Wadsworth Canal is approximately 4.3 miles in length and conveys runoff from southeast of the Sutter Buttes into the Sutter Bypass. The two interceptor channels act as collectors in the model and route flow towards an outflow node that is located at the beginning of the Wadsworth Canal. The outflow node contains a discharge rating curve that is based upon flood depths. This simulates drainage water flowing through the Wadsworth Canal and out of the basin. The Wadsworth Canal was not modeled as a FLO-2D channel due to model limitations regarding the backwater effects of the Sutter Bypass.

(4) Floodplain Roughness and Area Reduction Factors. Overland n-values and area reduction factors (ARF) were developed for a variety of different land uses. For consistency, the Manning's n and ARF values are based upon reference values utilized in recent USACE FLO-2D studies (which are based upon values listed in the FLO-2D User's Manual, as adapted from the 1990 HEC-1 User's Manual).

(5) Levees and Embankments. Levee elements were added to the FLO-2D model to represent the river channel levees and railroad embankments as found on the floodplain. The model includes the levees & embankments along the Sutter Bypass, Wadsworth Canal, Interceptor Canals, Cherokee Canal Feather River, and UPRR Embankment. The levee crest elevations were determined from the surveyed National Levee Database. The Union Pacific Railroad (UPRR) embankment elevations were based on field survey data obtained by the sponsor in May and June of 2009. The UPRR embankment elevations was input into the model based upon even grades between the survey points. The railroad embankment generally ranges in height from 1 to 7 feet above the existing terrain.

(6) Hydraulic Structures. Hydraulic structures were re-coded into the FLO-2D model using estimated stage-discharge rating curves developed from HEC-RAS, which utilizes a hydraulic gradient based upon the length between the two sides of the embankment. Five estimated rating curves (one for each different bridge length) were developed using HEC-RAS and then coded into FLO-2D.

(7) Pump Stations. Three pumping stations located within the Sutter basin were incorporated into the FLO-2D model. The pumping stations are maintained by the California Department of Water Resources (DWR) Sutter Maintenance Yard. All three pump stations transfer storm water runoff from inside the Sutter Basin into the Sutter Bypass. The plants are modeled as constant flow outflow nodes within the model. The pumping stations are assumed to be inoperable during the 0.2% (1/500) ACE scenario due to extensive flooding and power outages.

(8) Boundary Condition Inflows. The inflow hydrographs for the FLO-2D model consist of levee overtopping and breach hydrographs obtained from HEC-RAS model simulations. A

simulation run time of 720 hours was used in order to allow enough time for the flood waters to collect at the southern portion of the basin.

(9) Boundary Condition Outflows. The purpose of the FLO-2D model is to simulate the movement of breach floodwaters within the study area on the interior side of the Feather River and Sutter Bypass levee system. Therefore outflow elements were specified on the river side of the Sutter Bypass and Feather Rivers and the lowest part of the Butte Basin.

(10) Stage Uncertainty. The total combined standard deviation of stage uncertainty was estimated to be 1.2 feet using the equation above. The uncertainty of computed flood depths for the Sutter Basin FLO-2D model can primarily be attributed to the hydraulic modeling inaccuracies and the levee breach assumptions. The uncertainty was measured for a hypothetical breach along the Feather River at RM 57.17 using the 1% (1/100) ACE flood event (Shanghai storm centering). The uncertainties associated with roughness values and breach widths were evaluated. A detailed description of the stage uncertainty analysis is provided in the Sutter Basin Feasibility Study Hydraulics Report prepared by Peterson Brustad Inc. (SBFCA, 2012). The standard deviation (SD) of total stage uncertainty was calculated using the following equation provided in EM1110-2-1619.

$$\mathrm{SD}_{\mathrm{total}} = \sqrt{\mathrm{SD}_{\mathrm{model}}^2 + \mathrm{SD}_{\mathrm{breach}}^2}$$

$$\mathrm{SD}_{\mathrm{model}} = \sqrt{\mathrm{SD}_{\mathrm{topo}}^2 + \mathrm{SD}_{\mathrm{n-value}}^2}$$

The uncertainty in hydraulic model results is highly correlated to the uncertainty in the topographic data used to represent the geometric characteristics of the river reaches. The SD for topographic uncertainty is estimated to be 0.48 ft. This uncertainty value was based on the description of the topographic survey data provided in the Ayres Final Topographic Survey Report (AYRES, 2003)

The SD associated with roughness was estimated at two locations throughout the model. The values were estimated by computing water surface profiles with roughness values increased and decreased by 20 percent. The standard deviation was found to be 0.3 feet based on the average change in water surface elevation within the upper and lower inundation limits.

The SD associated with breach width was computed by simulating breach widths by +/-33%. The standard deviation was found to be 1.0 feet based on the average change in water surface elevation between the upper and lower inundation limits.

3.4 Hydraulic Model Results.

The hydraulic models described above were utilized to compute water surface profiles for two levee overtopping scenarios. Models were also utilized to simulate inundation depths within the study area from levee breach scenarios at 14 locations.

a. Levee Infinite Height Scenario (Scenario A). For this scenario, water surface profiles were simulated assuming all levees were infinitely high and would contain all flow within the infinite channel without overtopping. This scenario was used to evaluate the sensitivity of water surface elevations to levee overtopping assumptions. Infinite levee water surface profiles were developed for Sutter Bypass (Plate 12), Feather River (Plate 13), Wadsworth Canal (Plate 14), and Cherokee Canal (plates 15 and 16). Peak stage and flow frequency estimates at index points throughout the study area are presented in Tables 14 through 18. Peak stage frequency and flow frequency curves for the index points are provided in Plates 17 to 30.

b. Levee Overtopping Scenario (Scenario B). For this scenario, water surface profiles were based on the assumption that all Flood Risk Management levees can be overtopped but they do not fail. Peak stage and flow frequency tables for index points throughout the study area are presented in Tables 14 through 18. Peak stage frequency and flow frequency curves for the index points are provided in Plates 17 to 30.

Table 14
Feather River Hydraulic Characteristics, Alternative SB-1
Oroville Dam to Yuba River

Economic Index Point Location and Parameter	Flood Event Annual Chance of Exceedance (ACE)							
	Invert	50%	10%	4%	2%	1%	0.5%	0.2%
Feather River at RM 57.95 (Geotechnical Index MA 7 – 0.51) 1957 Design Top of Levee = 132.32 FT-NAVD88 2008 NLDB Top of Levee = 136.00 FT-NAVD88								
Controlling Storm Centering	-	SAC	SAC/SHY	SAC	SHY	SAC/SHY	SHY	SHY
Stage Uncertainty (Ft- 1 S.D.)	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Infinite Levee Model (Scenario A)								
Flow (CFS) 1/	0	60,000	100,000	150,000	150,000	150,000	174,000	320,400
Stage (FT-NAVD88)	96.13	118.95	123.97	127.58	127.58	127.58	128.84	131.27
Velocity (FPS)	0	5.43	7.28	8.10	8.22	8.22	8.50	9.00
Overtopping Levee Model (Scenario B)								
Flow (CFS) 1/	0	60,000	100,000	150,000	150,000	150,000	174,000	320,400
Stage (FT-NAVD88)	96.13	118.95	123.97	127.58	127.58	127.58	128.84	131.18
Velocity (FPS)	-	5.94	7.28	8.22	8.22	8.22	8.50	9.09
Feather River at RM 44.50 (Geotechnical Index MA 16 – 2.9) 1957 Design Top of Levee = 93.59 FT-NAVD88 2008 NLDB Top of Levee = 93.73 FT-NAVD88								
Controlling Storm Centering	-	SAC	SHY	SAC	SHY	SAC	SHY	SHY
Stage Uncertainty (Ft- 1 S.D.)	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Infinite Levee Model (Scenario A)								
Flow (CFS)	-	50,300	107,100	157,100	159,600	164,600	182,400	294,600
Stage (FT-NAVD88)	48.65	79.49	83.78	86.61	86.85	86.97	88.16	94.59
Velocity (FPS)	-	1.91	2.23	2.51	2.50	2.55	2.58	2.77
Overtopping Levee Model (Scenario B)								
Flow (CFS)	-	50,300	107,100	157,100	159,600	164,600	182,400	309,800
Stage (FT-NAVD88)	48.65	79.49	83.78	86.61	86.85	86.97	88.16	93.90
Velocity (FPS)	-	1.91	2.23	2.51	2.50	2.55	2.58	3.02
Feather River at RM 41.20 (Geotechnical Index MA 16 – 0.9) 1957 Design Top of Levee = 90.48 FT-NAVD88 2008 NLDB Top of Levee = 91.02 FT-NAVD88								
Controlling Storm Centering	-	SAC	SHY	SAC	SHY	SAC	SHY	SHY
Stage Uncertainty (Ft- 1 S.D.)	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Infinite Levee Model (Scenario A)								
Flow (CFS)	-	49,400	106,800	157,100	159,600	162,700	182,300	293,600
Stage (FT-NAVD88)	43.04	74.93	80.12	83.49	83.89	83.90	85.48	92.96
Velocity (FPS)	-	2.15	1.91	1.99	1.96	1.99	1.97	2.03
Overtopping Levee Model (Scenario B)								
Flow (CFS)	-	49,400	106,800	157,100	159,600	162,700	182,300	294,200
Stage (FT-NAVD88)	43.04	74.93	80.12	83.49	83.89	83.90	85.47	91.87
Velocity (FPS)	-	2.15	1.91	1.99	1.96	1.99	1.97	2.15
Feather River at RM 30.25 (Geotechnical Index LD9 – 0.52) 1957 Design Top of Levee = 84.17 FT-NAVD88 2008 NLDB Top of Levee = 86.52 FT-NAVD88								
Controlling Storm Centering	-	SHY	SHY	SAC	SHY	SHY	SHY	2/
Stage Uncertainty (Ft- 1 S.D.)	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Infinite Levee Model (Scenario A)								
Flow (CFS)	-	48,100	106,500	156,700	157,600	156,300	165,400	292,800
Stage (FT-NAVD88)	31.86	63.00	72.01	75.58	76.52	76.50	79.31	87.04
Velocity (FPS)	-	1.88	1.88	2.30	2.17	2.16	2.01	2.67
Overtopping Levee Model (Scenario B)								
Flow (CFS)	-	48,100	106,500	156,700	157,600	156,300	165,400	267,700
Stage (FT-NAVD88)	31.86	63.00	72.01	75.58	76.52	76.50	79.31	85.79
Velocity (FPS)	-	1.88	1.88	2.30	2.17	2.16	2.01	2.56

Notes:
1/ Flow at index point MA 7–0.51 is split into two parallel model reaches. Estimated flow is from cross section 60.81 upstream of split.
2/ Controlling Storm Centering for 0.2% ACE is SHY for Scenario A and SAC for Scenario B.

Table 15
Feather River Hydraulic Characteristics, Alternative SB-1
Yuba River to Sutter Bypass

Economic Index Point Location and Parameter	Flood Event Annual Chance of Exceedance (ACE)							
	Invert	50%	10%	4%	2%	1%	0.5%	0.2%
Feather River at RM 23.25 (Geotechnical Index LD1 – 9.31) 1957 Design Top of Levee = 76.87 FT-NAVD88 2008 NLDB Top of Levee = 78.50 FT-NAVD88								
Controlling Storm Centering	-	SHY	SHY	SHY	SHY	SAC	SHY	SHY
Stage Uncertainty (Ft- 1 S.D.)	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Infinite Levee Model (Scenario A)								
Flow (CFS)	-	71,100	192,800	257,000	281,800	283,700	361,900	535,900
Stage (FT-NAVD88)	19.36	53.30	63.06	66.50	67.74	67.96	71.36	77.80
Velocity (FPS)	-	3.72	3.08	3.22	3.27	3.25	3.46	3.90
Overtopping Levee Model (Scenario B)								
Flow (CFS)	-	71,100	192,800	257,000	281,800	283,800	361,900	522,700
Stage (FT-NAVD88)	19.36	53.30	63.06	66.50	67.73	67.94	71.35	76.56
Velocity (FPS)	-	3.72	3.08	3.22	3.27	3.25	3.46	3.99
Feather River at RM 16.75 (Geotechnical Index LD1 – 3.99) 1957 Design Top of Levee = 67.90 FT-NAVD88 2008 NLDB Top of Levee = 68.40 FT-NAVD88								
Controlling Storm Centering	-	SHY	SHY	SHY	SHY	SHY	SHY	SHY
Stage Uncertainty (Ft- 1 S.D.)	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Infinite Levee Model (Scenario A)								
Flow (CFS)	-	70,500	191,500	255,800	280,500	283,000	360,200	533,900
Stage (FT-NAVD88)	12.53	47.11	56.47	60.02	61.31	61.73	64.97	71.05
Velocity (FPS)	-	3.96	3.06	3.19	3.24	3.22	3.44	3.96
Overtopping Levee Model (Scenario B)								
Flow (CFS)	-	70,500	191,600	255,700	280,400	282,900	360,200	491,800
Stage (FT-NAVD88)	12.53	47.11	56.46	60.00	61.28	61.68	64.92	69.20
Velocity (FPS)	-	3.96	3.06	3.20	3.25	3.21	3.45	3.91
Feather River at RM 12.50 (Geotechnical Index MA 3 – 4.92) 1957 Design Top of Levee = 59.88 FT-NAVD88 NLDB Top of Levee = 64.59 FT-NAVD88								
Controlling Storm Centering	-	SHY	SHY	SHY	SHY	SAC	SHY	SAC
Stage Uncertainty (Ft- 1 S.D.)	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Infinite Levee Model (Scenario A)								
Flow (CFS)	-	53,900	151,800	209,700	233,300	240,800	305,000	449,800
Stage (FT-NAVD88)	16.77	43.87	50.88	53.95	55.19	55.98	58.44	63.14
Velocity (FPS)	-	1.44	2.29	2.64	2.75	2.73	3.09	3.78
Overtopping Levee Model (Scenario B)								
Flow (CFS)	-	53,900	151,500	209,000	232,300	239,600	304,000	403,600
Stage (FT-NAVD88)	16.77	43.83	50.83	53.90	55.14	55.90	58.34	61.63
Velocity (FPS)	-	1.44	2.29	2.63	2.74	2.73	3.09	3.59

Table 16
Sutter Bypass Hydraulic Charachteristics, Alternative SB-1

Economic Index Point Location and Parameter	Flood Event Annual Chance of Exceedance (ACE)							
	Invert	50%	10%	4%	2%	1%	0.5%	0.2%
Sutter Bypass at RM 84.31 (Geotechnical Index Sutter – 4) 1957 Design Top of Levee = 59.57 FT-NAVD88 2008 NLDB Top of Levee = 60.60 FT-NAVD88								
Controlling Storm Centering	-	SAC	SAC	SAC	SAC	SAC	SAC	SAC
Stage Uncertainty (Ft- 1 S.D.)	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Infinite Levee Model (Scenario A)								
Flow (CFS)	-	57,400	102,000	126,200	155,100	184,200	228,200	326,900
Stage (FT-NAVD88)	33.97	46.87	50.64	52.75	54.42	56.19	58.53	63.21
Velocity (FPS)	-	1.78	2.16	2.27	2.49	2.66	2.9	3.35
Overtopping Levee Model (Scenario B)								
Flow (CFS)	-	57,400	102,000	126,200	155,100	184,200	228,200	265,200
Stage (FT-NAVD88)	33.97	46.86	50.64	52.75	54.43	56.18	58.45	59.82
Velocity (FPS)	-	1.78	2.16	2.27	2.49	2.66	2.91	3.16
Sutter Bypass at RM 82.45 (Geotechnical IndexSutter – 6.2) 1957 Design Top of Levee = 58.73 FT-NAVD88 2008 NLDB Top of Levee = 58.30 FT-NAVD88								
Controlling Storm Centering	-	SAC	SAC	SAC	SAC	SAC	SAC	SAC
Stage Uncertainty (Ft- 1 S.D.)	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Infinite Levee Model (Scenario A)								
Flow (CFS)	-	57,700	102,800	126,800	156,000	185,000	229,000	327,200
Stage (FT-NAVD88)	29.28	44.95	49.08	51.41	53.03	54.82	57.15	61.83
Velocity (FPS)	-	1.69	2.04	2.13	2.36	2.53	2.78	3.23
Overtopping Levee Model (Scenario B)								
Flow (CFS)	-	57,700	102,800	126,800	156,000	185,100	227,900	247,800
Stage (FT-NAVD88)	29.28	44.92	49.08	51.42	53.04	54.81	57.06	58.51
Velocity (FPS)	-	1.69	2.04	2.13	2.36	2.53	2.78	2.82
Sutter Bypass at RM 72.17 (Geotechnical Index Sutter – 17.3) 1957 Design Top of Levee = 54.20 FT-NAVD88 2008 NLDB Top of Levee = 54.10 FT-NAVD88								
Controlling Storm Centering	-	SAC	SAC	SAC	SAC	SAC	SAC	SAC
Stage Uncertainty (Ft- 1 S.D.)	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Infinite Levee Model (Scenario A)								
Flow (CFS)	-	71,000	117,300	141,100	162,900	197,000	236,500	328,900
Stage (FT-NAVD88)	25.50	41.00	45.16	47.97	49.15	50.70	52.75	57.13
Velocity (FPS)	-	1.40	1.75	1.80	1.96	2.21	2.43	2.86
Overtopping Levee Model (Scenario B)								
Flow (CFS)	-	69,100	117,400	141,300	163,800	197,600	236,500	257,800
Stage (FT-NAVD88)	25.50	40.94	45.17	47.98	49.15	50.68	52.62	54.41
Velocity (FPS)	-	1.37	1.75	1.80	1.98	2.22	2.44	2.48

Table 17
Wadsworth Canal Hydraulic Characteristics, Alternative SB-1

Economic Index Point Location and Parameter	Flood Event Annual Chance of Exceedance (ACE)							
	Invert	50%	10%	4%	2%	1%	0.5%	0.2%
Wadsworth Canal at RM 4.54 1957 Design Top of Levee = 61.65 FT-NAVD88 2008 NLDB Top of Levee = 62.10 FT-NAVD88								
Controlling Storm Centering	-	WAD	WAD	WAD	WAD	WAD	WAD	WAD
Stage Uncertainty (Ft- 1 S.D.)	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Infinite Levee Model (Scenario A)								
Flow (CFS)	-	820	2250	3200	4000	4830	5750	7070
Stage (FT-NAVD88)	40.50	50.18	55.75	58.20	59.75	61.21	62.61	64.75
Velocity (FPS)	-	4.24	4.30	4.42	4.50	4.58	4.61	4.44
Overtopping Levee Model (Scenario B)								
Flow (CFS)	-	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Stage (FT-NAVD88)		N/A	N/A	N/A	N/A	N/A	N/A	N/A
Velocity (FPS)	-	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Wadsworth Canal at RM 0.81 (Geotechnical Index Wadsworth – 0.84 1957 Design Top of Levee = 59.35 FT-NAVD88 2008 NLDB Top of Levee = 58.80 FT-NAVD88								
Controlling Storm Centering	-	SAC	SAC	SAC	SAC	SAC	SAC	SAC
Stage Uncertainty (Ft- 1 S.D.)	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Infinite Levee Model (Scenario A)								
Flow (CFS)	-	820	2,250	3,200	4,000	4,830	5,750	7,070
Stage (FT-NAVD88)	36.35	46.88	50.67	52.79	54.46	56.23	58.57	63.24
Velocity (FPS)	-	0.54	1	1.18	1.3	1.39	1.41	1.32
Overtopping Levee Model (Scenario B)								
Flow (CFS)	-	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Stage (FT-NAVD88)		N/A	N/A	N/A	N/A	N/A	N/A	N/A
Velocity (FPS)	-	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Wadsworth Canal at RM 0.25 (Geotechnical Index Wadsworth– 0.5) (XS 0.19) 1957 Design Top of Levee = 59.35 FT-NAVD88 2008 NLDB Top of Levee = 60.30 FT-NAVD88								
Controlling Storm Centering	-	SAC	SAC	SAC	SAC	SAC	SAC	SAC
Stage Uncertainty (Ft- 1 S.D.)	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Infinite Levee Model (Scenario A)								
Flow (CFS)	-	820	2,250	3,200	4,000	4,830	5,750	7,070
Stage (FT-NAVD88)	37.06	46.87	50.65	52.76	54.43	56.20	58.54	63.21
Velocity (FPS)	-	0.47	0.86	1.03	1.13	1.2	1.23	1.16
Overtopping Levee Model (Scenario B)								
Flow (CFS)	-	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Stage (FT-NAVD88)		N/A	N/A	N/A	N/A	N/A	N/A	N/A
Velocity (FPS)	-	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Note: N/A - Scenario not modeled.
Velocities based on coincident peak Sutter Bypass stage and peak Wadsworth canal inflow. Velocities would be greater for a low Sutter bypass stage and peak Wadsworth canal inflow.

Table 18
Cherokee Canal Hydraulic Characteristics, Alternative SB-1

Economic Index Point Location and Parameter	Flood Event Annual Chance of Exceedance (ACE)							
	Invert	50%	10%	4%	2%	1%	0.5%	0.2%
Cherokee Canal Cherokee at RM 12.529 Geotech index Cherokee Canal– 9.5 1959 Design Top of Levee = 112.10 FT-NAVD88 2008 NLDB Top of Levee = 112.00 FT-NAVD88								
Controlling Storm Centering	-	CHK	CHK	CHK	CHK	CHK	CHK	CHK
Stage Uncertainty (Ft- 1 S.D.)	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2
Infinite Levee Model (Scenario A)								
Flow (CFS)	-	5,500	9,700	11,300	12,400	13,300	14,200	15,300
Stage (FT-NAVD88)	98.89	108.34	110.84	111.80	112.40	112.95	113.45	114.00
Velocity (FPS)	-	2.26	2.83	2.99	3.07	3.13	3.18	3.26
Overtopping Levee Model (Scenario B)								
Flow (CFS)	-	5,600	9,500	10,000	10,200	10,200	10,300	10,400
Stage (FT-NAVD88)	98.89	108.36	110.74	111.07	111.14	111.19	111.22	111.25
Velocity (FPS)	-	2.27	2.81	2.86	2.88	2.88	2.89	2.89

c. Levee Breach Scenarios. Inundation maps were developed for fifteen levee breach locations within the study area. These breach locations were spatially distributed throughout the study area to reflect the floodplain characteristics. All breach scenarios assume levees were overtopped without failure at all locations other than the breach location. Breaches were simulated for 50% (1/2) ACE, 10% (1/10) ACE, 4% (1/25) ACE, 2% (1/50) ACE, 1% (1/100) ACE, 0.5% (1/200) ACE, and 0.2% (1/500) ACE events. The resulting inundation maps are hypothetical simulations of levee failures and do not represent the probability of occurrence. A summary of the breach simulation locations is provided in Table 19.

Levee breaches are used to define the inundation if a breach were to occur. The probability of the breach is computed by the FDA model using the discharge-frequency, stage-discharge, failure probability (fragility curve), and their associated uncertainties.

The FLO-2D breach simulation models generate velocities and depths. However these were not post processed as velocity x depth. Only depth is used in the FDA model. For life safety evaluation a simple depth metric was used for alternative evaluations.

Table 19
Simulated Levee Breaches

Breach ID	River Mile	Horizontal Coordinates (FT- NAD83 CCS Zone II)		Breach Width (Feet)	Breach Elevation at Toe (FT-NAVD88)
		Northing	Easting		
Feather River					
FR 9.0 R	57.17	2283867	6661785	1500	115.00
FR 8.0 R	50.20	2258021	6662669	1500	95.74
FR 7.0 R	41.55	2225167	6665302	1500	41.59
FR 6.0 R	34.07	2201918	6666623	1500	69.54
FR 5.0 R	28.25	2178130	6672485	1500	55.82
FR 4.5 R	26.00	2167420	6673291	1500	52.20
FR 4.0 R	17.00	2128205	6675848	1500	45.38
FR 3.0 R	10.50	2095813	6680073	1500	36.45
Sutter Bypass					
SB 5.0 L	88.04	2168107	6626586	1000	39.90
SB 4.0 L	82.45	2158851	6631970	1000	37.36
SB 3.0 L	77.05	2131434	6640141	1000	28.96
Wadsworth Canal					
W2.0R	2.42	2178179	6634678	1000	39.90
W2.0L	2.42	2178079	6634839	1000	43.80
Cherokee Canal					
CC2.0L	13.34	2305152	6638905	50	103.00
CC1.0L	11.4	2296019	6634326	50	103.00

Eight breaches were simulated on the Feather River from the Thermalito Afterbay to the Sutter Bypass. Each breach was simulated using the HEC-RAS model and the breach outflow hydrograph was translated to the FLO-2D model to simulate the inundation area of the breach. A 1,500 foot wide breach width was used for the simulations. The breach width was based on sensitivity analysis presented in the F3 Sutter Basin Feasibility Study report. The size is based on historical breaches within the central valley and achieving a headwater depth to tailwater depth ratio of 0.90.

The breach was initiated at the beginning of the flood simulation and assumed to take 1-hour to develop to the full width. This was done to reflect the hydrologic floodwave assumptions. The comp study hydrographs assume a series of six 5-day floodwaves make up the 30-day hydrograph. They put the largest 5-day wave in the middle of the series. However, the sequence of these 5-day events is uncertain and the largest could be the first. A breach at the initiation of the 30-day wave would reflect the true 30-day flow duration. Breach inundation maps are shown on Plates 31 to 38.

Three breaches were simulated on the Sutter Bypass between Wadsworth Canal and Feather River. Each breach was simulated using the HEC-RAS model and the breach outflow hydrograph was translated to the FLO-2D model to simulate the inundation area of the breach. A 1,000 foot wide breach width was used for the simulations. The breach width was based on sensitivity analysis presented in the F3 Sutter Basin Feasibility Study report. The size is based on historical breaches within the central valley and achieving a headwater depth to tailwater depth ratio of 0.90. Similar to the Feather River breach simulations, the breach was initiated at the beginning of the flood simulation and assumed to take 1-hour to develop to the full width. Breach inundation maps are shown on Plates 39 to 41.

One breach was simulated on the left bank of Wadsworth Canal. The breach was simulated using the HEC-RAS model and the breach outflow hydrograph was translated to the FLO-2D model to simulate the inundation area of the breach. The characteristics of this breach were assumed to be very similar as a breach on the Sutter Bypass because the volume of flow through the breach would originate from the Sutter Bypass. Therefore a 1,000 foot wide breach width was used for the simulations. The breach was initiated at the beginning of the flood simulation and assumed to take 1-hour to develop to the full width. Breach inundation maps are shown on Plate 42.

One breach was simulated on the right bank of Wadsworth Canal. A breach on the right bank levee of the Wadsworth Canal would flood a triangular area between Wadsworth Canal, the Sutter Bypass, and the natural ground elevation south of the Town of Sutter. It was assumed the volume of the Sutter Bypass flood hydrograph would be sufficient to fill this volume to the stage of the channel at the breach location. The breach inundation was simulated by projecting the channel stage on the FLO-2D grid elevations and computing the resulting depths. The breach inundation maps are shown on Plate 43.

Two breaches were simulated on Cherokee Canal upstream and downstream of the Union Pacific Railroad. Each breach was simulated using the HEC-RAS model and the breach outflow hydrograph was translated to the FLO-2D model to simulate the inundation area of the breach. A 50 foot wide breach width was used for the simulations. The breach width was based on historical breach occurrences along the Cherokee Canal. For Cherokee Canal, the PDT was considering the use of FIA modeling where inundation time and velocities plays a role in the calculations. The breach was initiated 1-hour before the peak flood stage and assumed to take 1-hour to develop to the full width. Breach inundation maps are shown on Plates 44 and 45.

d. Natural (Non-Breach) Inundation. Flood depth inundation maps were developed for two natural (non-breach) flood sources within the study area. These sources of flooding are from interior drainage and flood storage within the Butte Basin.

Flood depths from interior drainage were obtained from analysis performed by Peterson-Brustad Incorporated (PBI) a consultant to the Sutter Butte Flood Control Agency (SBFCA). The interior drainage analysis evaluated rainfall runoff and flood depths for 2% (1/50) ACE, 1% (1/100) ACE, 0.5% (1/200) ACE flood events. These maps indicated flooding was limited to non-urban areas and flooding from levee breach sources were far greater sources of damage. Therefore, maps were limited to these three events. Inundation maps from interior flooding are shown on Plate 46.

Flood depths within the Butte Basin were obtained from the Sacramento San Joaquin Comprehensive Study model results. The model is described above. Inundation within the Butte Basin was simulated by projecting the model stage on the FLO-2D grid elevations and computing the resulting depths. Inundation was simulated for 50% (1/2) ACE, 10% (1/10) ACE, 4% (1/25) ACE, 2% (1/50) ACE, 1% (1/100) ACE, 0.5% (1/200) ACE, and 0.2% (1/500) ACE events. The breach inundation maps are shown on Plate 47.

3.5 Hydraulic Design.

Alternative SB1 is the without project condition and does not include any features requiring hydraulic design.

3.6 Wind Wave Analysis.

An analysis of wind wave runup and wind setup was conducted for the east levee of the Sutter Bypass and west levee of the Feather River. The analysis did not include Cherokee Canal or Wadsworth Canal because wind waves were not considered to be a significant factor in these reaches because their fetch lengths are less than 400 feet. The complete analysis is described in the report "Sutter Basin wave runup analysis", 15 July 2011. The analysis was performed for three representative sites on the Sutter Bypass and seven representative sites along the Feather River. Results for wind wave run up and setup up for a hypothetical water level at the levee crest are summarized in Tables 20 and 21.

The wind wave run-up calculations were made assuming they could be incorporated into the HEC-FDA model used to compute economic flood damages. However it was later determined that this module in FDA does not work and the results could not be utilized. However, the information is useful to assess the probability of wind wave overtopping. The information was also used to evaluate the performance relative the California State Urban Levee Design Criteria (ULDC).

Wind wave runup and setup were evaluated for three wind speed scenarios over a range of four flood stages. These results could then be interpolated depending on the needs of the study. An analysis of wind speed and flood stage found very low correlation. This indicated that wind wave run-up could be assessed independently of flood frequency. In addition, it was found that wind wave runup and setup were largely independent of water surface elevation in the top 2/3 of the levee height. At these depths the fetch lengths are similar and the waves are not depth limited.

The minimum probable wind scenario was based on the minimum of the annual maximum wind speeds. The most likely wind scenario was based on the average of the annual maximum wind speeds. The maximum probable wind scenario was based on the annual maximum wind speeds. The wind analyses were based on 80 years of record at the Sacramento Executive Airport wind gage.

For each of the wind scenarios, wind wave runup was calculated for four water levels corresponding to the levee toe, 1/3 height, 2/3 height, and top of levee. As described above, it was found that wind wave runup and setup were largely independent of water surface in the top 2/3 of the levee height. Therefore, only the wind wave runup and setup result for the top of levee stage are provided in the Table.

Table 20
Estimated Wind Wave Runup and Setup at Top of Levee
Feather River West Levee, Alternative SB-1

Reach River Mile	Reach Name	Comp Study River Mile	Wind Wave Analysis Index Point	Wind Scenario	Wind Stress	Wave Runup Ru2% (Feet)	Wind Setup (Feet)
58.75							
	Feather River North Upper	48.85	WW-FR7	Probable High Most Likely Probable Low	82.5 mph 40.7 mph 23.1 mph	7.06 4.52 2.43	0.46 0.15 0.04
48.85							
	Feather River North Middle	43.28	WW-FR6	Probable High Most Likely Probable Low	66.5 mph 40.7 mph 23.1 mph	5.01 2.90 2.43	0.15 0.03 0.01
38.71							
	Feather River North Lower	35.78	WW-FR5	Probable High Most Likely Probable Low	72.3 mph 40.7 mph 23.1 mph	4.67 2.90 1.81	0.10 0.03 0.01
30.25							
	Feather River South Shanghai	27.50	WW-FR4	Probable High Most Likely Probable Low	66.5 mph 37.2 mph 27.3 mph	3.74 1.60 1.24	0.07 0.01 0.00
20							
	Feather River South Abbot	19.25	WW-FR3	Probable High Most Likely Probable Low	72.3 mph 40.7 mph 23.1 mph	5.26 3.26 2.03	0.12 0.04 0.01
15.5							
	Feather River South Bear	11.75	WW-FR2	Probable High Most Likely Probable Low	66.5 mph 40.7 mph 23.1 mph	5.41 3.06 1.91	0.15 0.04 0.01
7.5							

Table 21
Estimated Wind Wave Runup and Setup at Top of Levee
Sutter Bypass East Levee, Alternative SB-1

Reach River Mile	Reach Name	Comp Study River Mile	Wind Wave Analysis Index Point	Wind Scenario	Wind Stress	Wave Runup Ru2% (Feet)	Wind Setup (Feet)
87.86							
	Sutter Bypass above Wadsworth	86.18	WW-SB1	Probable High Most Likely Probable Low	82.5 mph 39.9 mph 24.4 mph	3.67 2.00 1.33	0.12 0.03 0.01
83.62							
	Sutter Bypass Upper	80.96	WW-SB2	Probable High Most Likely Probable Low	105.8 mph 36.0 mph 18.5 mph	4.39 1.84 1.33	0.15 0.02 0.01
75.3							
	Sutter Bypass Lower	70.12	WW-SB3	Probable High Most Likely Probable Low	82.5 mph 39.9 mph 24.4 mph	3.67 2.00 1.33	0.11 0.03 0.01
66.3							

3.7 Sedimentation and Channel Stability. An evaluation of sedimentation and channel stability was based on existing studies. The following gives a brief description of the Sutter Bypass, Feather River, and Cherokee Canal.

a. Sutter Bypass. The Sutter Bypass follows the low point of the historic Sutter Basin. Prior to construction of the Sacramento River Flood Protection project the Sutter Basin was a natural overflow area adjacent to natural levees of the Sacramento and Feather Rivers.

The Sutter Bypass is a depositional feature. The rate of sediment deposition along the Sutter Bypass from Long Bridge to Tisdale Weir has been estimated to be 135,000 tons/yr. The deposition rate from Tisdale Weir to Highway 113 (upstream of the Feather River confluence) has been estimated to be 683,000 tons per year. These rates were estimated as part of the 1970 Sacramento River and Tributaries Bank Protection and Erosion Control Investigation. The results were based on an evaluation of sediment transport capacities and are presented in a 4 September, 1986 USACE information pamphlet for Field Reconnaissance Visit of U.S.- Japan Cooperative Science Project on River Meandering (NSF). Deposition rates from the Feather River to the Sacramento River are estimated at 400,000 tons per year based on a comparison of 1939 and 1979 topographic profiles across the bypass. The USACE report concluded that "a significant" portion of the sediment deposited in the lower bypass was derived from the Feather River System.

The Sutter Bypass is inspected as part of the Sacramento River Bank Protection Project. The last complete inspection of the Sutter Bypass east levee occurred in 2011. One active site was identified at RM 77.2 and was 160 feet long. The site was reported to be a slump caused by wind wave erosion.

b. Upper Feather River (River Mile 61-28). The upper Feather River reach extends from Oroville to the mouth of the Yuba River. Within this reach the levee embankment system on the upper Feather River is set back, and the river occupies a wide meander belt similar to the Sacramento River upstream of Colusa. The Lower Feather River is estimated to be degrading. This reach is inspected for erosion sites as part of the Sacramento River Bank Protection Project. The last complete inspection of the Feather River occurred in 2011. One active site was identified at RM 47.6 and was 850 feet long. The site was reported to be scour along the waterside levee toe.

The upper Feather River is significantly different from the lower Feather River in that it did not receive the tremendous sediment influx from hydraulic mining from the Yuba River. Although hydraulic mining took place on the upper Feather River, the amount of material introduced to the river was significantly less. As with all other locations disturbed by the hydraulic mining debris, the upper Feather River aggraded during the late 19th century due to the influx of sediment. Subsequently, the river has degraded into the debris. In addition to hydraulic mining sediments, the river itself was dredged and the tailings were deposited in mounds which essentially block the hydraulic conveyance of the overbank. Construction of the Oroville Dam has altered the hydrology significantly and has reduced the sediment load.

From Oroville Dam to River mile 56, Gold mining dredge spoils border the river. As high flows bypass the majority of dredge spoils via the Thermalito Afterbay, coarse sediment within the spoils is rarely transported. In this reach the sinuosity is low, split flow around mid channel bars is common, and sediment is dominated by coarse gravel to cobble-sized materials. From River Mile 56 to River Mile 44.2 (Honcut Creek) the Feather River is a sand to fine gravel-dominated, high sinuosity stream.

From River Mile 44.2 to River Mile 27 (Yuba River) the Feather River is a sinuous, meandering river whose bed material is dominated by sand to fine gravel-size sediment. The river is highly dynamic and contains large point bars and chute channels. Bank erosion is extensive; however, wide levee setback precludes direct levee threat. Where the channel flows close to the levee, Modesto outcrops compose the channel banks, resisting erosion. Sand channels are commonly preserved in the bank stratigraphy, suggesting that during hydraulic mining, large quantities of sand were stored within this reach. Vegetation displaying distinct adventitious root zones also records a period of rapid aggradation. Point bars generally consist of sand-sized sediment. Active point bar growth, chute cutoffs and bendway migration are evidenced active bank erosion and active chutes across the bars.

Sediments that make up the active channel and floodplain deposits of the upper Feather River can be divided into Holocene (recent) and Pleistocene ages. The Pleistocene deposits affecting the river include the Riverbank and Modesto Formations. Pleistocene sedimentary rocks of the Riverbank and Modesto Formations bound the active meanderbelt of the upper Feather River. .The Modesto Formation is the most common bounding unit, bordering the Feather River meanderbelt along the line of the project levees. Consequently, as the river approaches the levee, in many cases lateral migration is effectively arrested as it encounters resistant sediments of the Modesto Formation, similar to the Sacramento River upstream of Colusa. The Modesto Formation consists of fluvial sediments that include channel fill, point bar, and lateral and vertical accretion deposits. It is generally cohesive and resistant to erosion.

Modes of bank failure that occur on the Feather River study reach are highly dependent on bank lithology and stratigraphy. There is a great deal of erosion happening from RM 45-28. Here the channel is sinuous and actively meandering.

Migration rates are highly variable along the Feather River study reach, reflecting the heterogeneity of materials present, and the range of stages of bend development. Although bankline migration rates are commonly high, levee setback is sufficient so that very little direct levee threat can be demonstrated on the Feather River. From RM 45-28 the channel bed has degraded over time.

b. Lower Feather River (River Mile 28 to 0). The Lower Feather River extends from the Yuba River to the Sacramento River opposite the Fremont Weir. The Lower Feather River estimated to be degrading. This reach is inspected for erosion sites as part of the Sacramento River Bank Protection Project. The last complete inspection of the Feather River occurred in 2011. No active erosion sites were identified.

The lower Feather River reach is presently a wide, low sinuosity, sand-dominated system that is presently sediment-laden. The bed of the Feather River in this reach contains large sand waves, which were observed to be slowly migrating downstream under relatively low flow conditions of mid-summer. These sand waves are generally several hundred feet long and several hundred feet wide, occupying the majority of the channel width. Generally the sinuosity decreases in the downstream direction.

The river planform of this reach prior to 1850 was much like the present-day Sacramento River. Hydraulic mining has had a severe effect on the lower Feather River. The initial surge of hydraulic mining debris in the Feather River consisted of silts and clays known as "slickens". Later on, floods brought down coarser sediment that overlaid the slickens. The average fill thickness in the Feather River from the mouth of the Yuba River to Nicolaus was 20 feet. The original sinuous channel was completely in filled. The high sediment loads caused the rate of bendway cutoffs to increase and the channel sinuosity decreased (slope increased) as a result. Alternate bars formed in response to the generally increased sediment load. The channel was a wide, shallow, sand-dominated system that had low, ill-defined banks, which were commonly overtopped. Levees were later put in place to prevent flooding.

After hydraulic mining was discontinued, the subsequent reduction in sediment load caused the river to incise into the hydraulic mining debris. Degradation of the hydraulic mining has since mostly come to an end. The channel maintained its low sinuosity as it incised, preserving bars as perched geomorphic features. The stratigraphy into which the channel incised consists of clean mining derived sands underlain by fine-grained, thinly bedded silts and clays of the slickens. The slickens add stability to the Feather River system, as the fine-grained sediments commonly form a cohesive toe. Recent data indicate, however, that the Feather River has locally eroded through the slickens such that the lowermost parts of the banks below the water may be composed of pre-hydraulic mining deposits. If the channel has eroded into the sands, then it is important to consider potential ramifications of the changing erodibility of the channel perimeter. Though the Feather River is sand-dominated there is also evidence of coarser materials being deposited from the Yuba River.

The slickens are laterally continuous and very homogeneous, and therefore display little variability in terms of erosion resistance for a given stratigraphic horizon. The slickens are underlain by pre-hydraulic mining Feather River meanderbelt deposits. These older deposits are likely to be much more heterogeneous than those exposed along the river today, in that they were deposited in a coarse grained meanderbelt, much like the Sacramento River above Colusa. Such material diversity will likely result in variable erosion rates, causing planform adjustment to the differences in resistance of materials encountered following degradation. Any rapid lateral adjustment of the river could in turn create a threat to bordering flood control levees.

The erosion-resistant nature of the Modesto Formation has resulted in the formation of a steep knick zone that contains over 5 feet of drop in bed elevation in a few hundred feet of channel. The report indicates the location as river mile 24.8. This headcut has migrated upstream as a horseshoe-shaped feature. Migration of the headcut upstream has serious implications with respect to upstream continuation of the degradation.

Bank failure mechanisms on the Feather River are highly correlated to bank stratigraphy. Sand-sized sediment is derived from Feather River bank erosion as well as from tributaries. Upper bank sediments on this reach of the Feather River commonly consist of clean sands underlain by a fine-grained cohesive toe. Both of these units represent hydraulic mining debris deposited during the aggradational period of the hydraulic mining era. The upper bank unit is prone to erosion and contributes sand size sediment to the system. Bed sediments consist primarily of sand. Where the bank stratigraphy is not the coarsening upward hydraulic mining sequence, it is generally Pleistocene-age Modesto Formation. The Modesto Formation consists of tan and light gray gravely sand, silt, and clay. Both types of bank materials are relatively erosion resistant at the bank toe and are responsible for the low bank erosion rates in the study reach. In general the Modesto Formation forms a high bank that is highly resistant to erosion and is therefore capable of significant bendway distortion and planform control.

As mentioned previously, the sinuosity generally increases in the upstream direction in this reach of the Feather River. An increase in sinuosity in the upstream direction reflects the increasing amount of Modesto outcrop exposed in the channel banks, which has helped to maintain channel planform. The channel has incised into the cohesive slickens, which has also helped to maintain the channel planform. Flow control in the watershed has also contributed to the maintenance of channel planform. Though the river is largely stable, if the river degrades through the slickens and high shear stresses are imparted on less cohesive underlying bank strata, channel migration rates and sinuosity may increase due to the significant bank erosion and development of channel asymmetry. As the supply of sand to the study reach appears relatively constant and incision rates have slowed significantly since the early part of this century, incision into underlying strata may not be imminent.

d. Wadsworth Canal. The Wadsworth Canal is a leveed channel which conveys interior drainage into the Sutter Bypass. A search of past studies and reports found no information about sedimentation rates in the canal. This reach is inspected for erosion sites as part of the Sacramento River Bank Protection Project. The last complete inspection of the Wadsworth Canal occurred in 2011. Two erosion sites were identified. Site WAD_2-1_L is located on the left bank and extends from River Mile 2.25 to River Mile 1.8. The site was identified as a bank failure with leaning trees and exposed roots. Site WAD_2-4L is also located on the left bank and extends from River Mile 3.15 to River Mile 2.2. The site was identified as a bank failure.

e. Cherokee Canal. Cherokee Canal is a leveed channel that conveys runoff from the Clear Creek, Dry Creek, Gold Run Creek, and Cottonwood Creek watersheds to Butte Slough. DWR has completed several sediment removal projects along the canal to maintain the design capacity. A sediment yield and transport study was completed by URS Corporation for the Sacramento District in January 2003. The study indicated the channel is depositional. Cherokee Canal is not inspected for bank erosion by the Sacramento Bank Protection Project.

3.8 Flood Risk.

Flood risk is defined as the probability of a flood event occurring and the consequences of occurrence. Flood risk was assessed using the USACE FDA model version 1.2.5a (USACE, 2010). The FDA model combines flow-frequency, stage-discharge, geotechnical fragility, and stage-damage relationships to estimate damages. Uncertainty in each relationship is incorporated by assigning uncertainty estimates and applying a Monte Carlo type approach to combine the results.

Flow-frequency, stage discharge, and geotechnical frequency relationships reflect the exterior (probability) side of the risk calculations. Inundation depth and stage-damage relationships reflect the interior (consequence) side of the risk calculations. For the probability side of the risk calculations, the hydraulic model assumptions are based on flows contained to the channel (allowed to overtop without failure). For the consequence side of the risk calculations, the hydraulic model assumptions are based on levee breach failure or simply the depth for natural overbank (non-levee) conditions.

The risk assessment approach included an evaluation of potential flood sources with respect to geotechnical fragility, channel hydrology, channel hydraulics, and potential inundation patterns of a levee breach or natural overbank (non-levee). Thirteen geotechnical reaches were identified. Within each of the geotechnical reaches a representative geotechnical fragility curve was developed and a stage-discharge relationship was developed using a system based hydraulic model. Selection of the geotechnical reaches is described in detail in the geotechnical analysis report. Fifteen breach sources and one non-leveed flood sources were identified. All breach source locations identified within a geotechnical reach were assigned to the same geotechnical fragility curve location.

a. Levee Assurance. The reliability of Flood Risk Management (FRM) features within the study area is expressed as an assurance level (conditional non-exceedance probability) for a given median ACE hydrologic event. The assurance varies over levee reaches due to variations in geotechnical fragility, hydrology, and hydraulic characteristics and their uncertainties.

Levee assurance was computed for the 13 geotechnical reaches within the study area using the HEC-FDA computer program. The reaches are shown on Plate 48 and described in Tables 22 through 26. Assurance was calculated at the geotechnical fragility curve location within each reach and assumed to represent the assurance throughout the entire reach. Assurance was calculated with the HEC-FDA program using an unregulated flow-frequency curve, unregulated to regulated transform, stage-discharge relationships, geotechnical fragility curves, and Hydraulic Top of Levee Elevation (HTOL). Uncertainty in each relationship was incorporated using the FDA Monte Carlo simulation. Wind wave runup and setup were not included in the assurance calculations. FDA input assumptions are described in Tables 22 through 26.

Flow-frequency curves were based on the analytical statistics computed for unregulated conditions. Uncertainty in the flow-frequency curve is based on the period of record described in the hydrology section above. For the Sutter Bypass and Feather Rivers, the nearest upstream analytical curve statistics were utilized in combination with an unregulated-regulated transform. The unregulated flow in the transform is computed directly from the flow frequency statistics. The regulated flow used in the transform was obtained from the hydraulic model at the index location (Tables 14 -18). The transforms are used to translate the uncertainty in flow frequency estimates to the regulated condition.

The geotechnical fragility curves were based on geotechnical analysis and are presented in the geotechnical appendix and provided as Attachment B to this report. The curves are assumed to have a 100% probability of failure at the levee crest. The crest elevation was modified in the

FDA model to reflect the Hydraulic Top of Levee (HTOL). The hydraulic top of levee is defined as the elevation at the index point corresponding to the first point of overtopping within the reach. The HTOL is lower than the actual top of levee at index points with high localized crest elevations.

Stage discharge curves used in the analysis are described in Tables 14 through 18. For index points that represent the first levee segment downstream of high ground, stages and flows are based on Scenario A (infinite levee height). This was done to prevent overestimating the assurance within these reaches. The overestimate would occur if upstream overtopping reduces the flow and stage at the index point but the overtopping failure is not accounted for in the performance evaluation.

Table 22
FDA Input for Feather River West Levee Performance Calculations
Alternative SB-1

Reach River Mile	Reach Name	Index Point Comp Study River Mile	Hydraulic Top of Levee (FT-NAVD88)	Geotechnical Fragility Curve	Hydraulic Model Overtopping Scenario	Unregulated Flow Frequency Curve	Notes
58.75							
	Feather River North Upper	57.95	129.62	MA7- Ham Bend	A	at Oroville with Regulated Transform	- Represents Breaches F9.0R, F8.0R - HTOL based on overtopping at RM 58.25 - NLDB TOL 136.00 FT-88
48.85							
	Feather River North Middle	41.20	91.02 (NLDB)	MA16-0.9	B	at Oroville with Regulated Transform	- Represents Breaches F7.0R
38.71							
	Feather River North Lower	30.25	85.01	LD9-0.52	B	at Oroville with Regulated Transform	-Represents Breaches F6.0R, F5.0R - HTOL based on overtopping at RM 32.35 - NLDB TOL 86.52 FT-88
30.25							
	Feather River South Shanghai	23.25	75.79	LD1-9.31	B	at Shanghai with Regulated Transform	- Assumes gate closure at Railroad. - Represents Breaches F4.5R, F4.4R - HTOL based on overtopping at RM 27.19 - NLDB TOL 78.50 FT-88
20							
	Feather River South Abbot	16.75	67.53	LD1-3.99	B	at Shanghai with Regulated Transform	- Represents Breaches F4.1R, F4.0R - HTOL based on overtopping at RM 19.28 - NLDB TOL 68.50 FT-88
15.5							
	Feather River South Bear	12.50	60.75	MA3-4.92	B	at Shanghai with Regulated Transform	- Represents Breaches F3.0R - HTOL based on overtopping at RM 9.18 - NLDB TOL 64.60 FT-88
7.5							
NLDB - Top of Levee in 2008 National Levee Database							

Table 23
FDA Input for Sutter Bypass East Levee Performance Calculations
Alternative SB-1

Reach River Mile	Reach Name	Index Point Comp Study River Mile	Hydraulic Top of Levee (FT-NAVD88)	Geotechnical Fragility Curve	Hydraulic Model Overtopping Scenario	Unregulated Flow Frequency Curve	Notes
87.86							
	Sutter Bypass above Wadsworth	83.70	59.21	Sutter-4	B	at Ord Ferry with Regulated Transform	- Model XSEC 84.31 - Represents Breach S5.0L - HTOL based on overtopping at RM 85.19 - NLDB TOL 60.60 FT-88
83.62							
	Sutter Bypass Upper	81.92	57.72	Sutter - 6.2	B	at Ord Ferry with Regulated Transform	- Model XSEC 82.45 - Represents Breach S4.0L - HTOL based on overtopping at RM 83.53 - NLDB TOL 58.20 FT-88
75.3							
	Sutter Bypass Lower	71.65	52.93	Sutter - 17.3	B	at Ord Ferry with Regulated Transform	Model XSEC 72.17 -Represents Breach S3.0L - HTOL based on overtopping at RM 66.3 - NLDB TOL 54.10 FT-88
66.3							
NLDB - Top of Levee in National Levee Database							

Table 24
FDA Input for Wadsworth Canal South Levee Performance Calculations
Alternative SB-1

Reach River Mile	Reach Name	Index Point Comp Study River Mile	Hydraulic Top of Levee (FT-NAVD88)	Geotechnical Fragility Curve	Hydraulic Model Overtopping Scenario	Unregulated Flow Frequency Curve	Notes
4.54							
	Wadsworth Canal at Interceptor Canals	4.54	62.10 (NLDB)	None	A	Wadsworth Canal nr Sutter	- No breach represented
4.50							
	Wadsworth Canal Left Levee	0.81	58.80 (NLDB)	Wadsworth LB- 0.83	A	None	- Based on Stage Frequency Curve - Represents Breach WC 2.0L
0							
NLDB - Top of Levee in National Levee Database							

Table 25
FDA Input for Wadsworth Canal North Levee Performance Calculations
Alternative SB-1

Reach River Mile	Reach Name	Index Point Comp Study River Mile	Hydraulic Top of Levee (FT-NAVD88)	Geotechnical Fragility Curve	Hydraulic Model Overtopping Scenario	Unregulated Flow Frequency Curve	Notes
4.54							
	Wadsworth Canal at Interceptor Canals	4.54	62.10 (NLDB)	None	A	Wadsworth Canal nr Sutter	- No breach represented
4.50							
	Wadsworth Canal Right Levee	0.25	60.30 (NLDB)	Wadsworth RB- 0.83	A	None	- Based on Stage Frequency Curve - Represents Breach WC 2.0R
0							
NLDB - Top of Levee in National Levee Database							

Table 26
FDA Input for Cherokee Canal South Levee Performance Calculations
Alternative SB-1

Reach River Mile	Reach Name	Index Point Comp Study River Mile	Hydraulic Top of Levee (FT-NAVD88)	Geotechnical Fragility Curve	Hydraulic Model Overtopping Scenario	Unregulated Flow Frequency Curve	Notes
15.7							
	Cotton Wood Creek to Hwy 162	12.53	110.6 (NLDB)	Cherokee 9.50	A	Cherokee Canal nr Richvale	- Represents Breaches CC1.0L and CC 2.0 L - HTOL based on overtopping at RM 13.42 - NLDB TOL 112.00 FT NAVD88
10.8							
NLDB - Top of Levee in National Levee Database							

b. Composite Flood Depths. Maps showing composite floodplains were developed to demonstrate FRM assurance relative to a standard assurance criterion. The maps show inundation from any flood source that would not meet a risk and uncertainty based assurance criterion. The assurance criterion was based on the NFIP levee system analysis criteria described in EC 1110-2-6067 and was adopted for use in describing the performance of all ACE events. This criterion is described as “Option 2” in the DWR Urban Levee Design Criteria. The assurance criterion utilized for this study does not account for wind wave overtopping.

- For assurance less than 90% the levee does not pass criteria
- For assurance between 90 and 95% levee must have minimum of 3 feet of freeboard to pass criteria.
- For assurance greater than 95% levee must have minimum of 2 feet of freeboard to pass criteria.

The composite floodplains are provided in Plates 49 through 56. All maps include the natural (non-leveed) flood inundation depths. Table27 provides performance values at simulated breach locations. These maps demonstrate the variation of flood risk management assurance throughout the study area.

Table 27
Project Performance at Simulated Levee Breach Locations, Alternative SB-1

Simulated Breach		Annual Exceedance Probability		Long Term Risk			Flood Risk Management Assurance by Event Flood Frequency (Breach included in floodplain map if shaded)						
Label	River Mile	Median	Exp.	10 Years	30 Years	50 Years	50% ACE	10% ACE	4% ACE	2% ACE	1% ACE	0.5% ACE	0.2% ACE
Feather River													
F9.0R	57.17	0.0696	0.0769	0.5506	0.9092	0.9817	0.9909	0.8187	0.6499	0.6087	0.5777	0.4781	0.331
F8.0R	50.20	0.0686	0.0768	0.5504	0.9091	0.9816	0.9909	0.8187	0.6499	0.6087	0.5777	0.4781	0.331
F7.0R	41.55	0.0203	0.0238	0.2138	0.5140	0.6996	0.9999	0.9299	0.7965	0.7586	0.7209	0.5657	0.298
F6.0R	34.07	0.0353	0.0391	0.3286	0.6973	0.8635	0.9999	0.848	0.744	0.6685	0.5995	0.4486	0.2193
F5.0R	28.25	0.0353	0.0391	0.3286	0.6973	0.8635	0.9999	0.848	0.744	0.6685	0.5995	0.4486	0.2193
F4.5R	26.00	0.0909	0.1071	0.6778	0.9666	0.9965	0.9838	0.8025	0.6253	0.581	0.5626	0.4788	0.2988
F4.4R	25.99	0.0909	0.1071	0.6778	0.9666	0.9965	0.9838	0.8025	0.6253	0.581	0.5626	0.4788	0.2988
F4.1R	17.00	0.0622	0.0676	0.5036	0.8777	0.9699	0.9999	0.7722	0.6232	0.5759	0.5396	0.3996	0.175
F4.0R	16.99	0.0622	0.0676	0.5036	0.8777	0.9699	0.9999	0.7722	0.6232	0.5759	0.5396	0.3996	0.175
F3.0R	10.50	0.0167	0.0192	0.1766	0.4418	0.6216	0.9999	0.9443	0.9171	0.889	0.8447	0.6847	0.4057
Sutter Bypass													
S5.0L	88.04	0.2184	0.2331	0.9297	0.9997	0.9999	0.8232	0.5684	0.4267	0.3803	0.2991	0.1896	0.0827
S4.0L	82.45	0.4468	0.5156	0.9993	0.9999	0.9999	0.5362	0.3336	0.3257	0.2956	0.2223	0.1391	0.0631
S3.0L	77.05	0.1945	0.2104	0.9058	0.9992	0.9999	0.8101	0.6612	0.635	0.6009	0.5021	0.3426	0.1654
Wadsworth Canal													
W3.0R	4.54	0.0065	0.0086	0.0826	0.2279	0.3501	0.9999	0.9995	0.9951	0.9338	0.705	0.3791	0.0786
W2.0R	2.42	0.3590	0.3577	0.9880	0.9999	0.9999	0.6394	0.3611	0.239	0.2263	0.1884	0.0874	0.0074
W2.0L	2.42	0.1137	0.1157	0.7075	0.9750	0.9979	0.9583	0.7575	0.5626	0.4783	0.3363	0.1392	0.0056
Cherokee Canal													
CC2.0L	13.34	0.2616	0.2803	0.9627	0.9999	0.9999	0.8618	0.3115	0.1005	0.0373	0.0142	0.0061	0.0015
CC1.0L	11.4	0.2616	0.2803	0.9627	0.9999	0.9999	0.8618	0.3115	0.1005	0.0373	0.0142	0.0061	0.0015
Notes: Assurance based on existing top of levee or 1957 design top of levee, whichever is higher within the reach. Assurance accounts for stage uncertainty, hydrologic uncertainty, and geotechnical uncertainty.													

d. Flood Velocities. The average velocity within the floodway is provided in Tables 14 through 18. If a levee breach were to occur, inundation velocities and depths within the study area would vary by proximity to a breach, breach location, and magnitude of flood event. The velocity field for a levee breach can be characterized as highest near the breach due to the rapidly varying flow conditions. The remaining area would have lower velocities associated with the slope of the topography and floodplain roughness. For evaluation of life loss consequence the study area can be divided into a breach zone, zone with rapidly rising water, and a remaining zone (Yonkman, 2008). The simulated levee breach at F9.0R during a 1% (1/100) ACE event is representative of the study area.

(1) Breach zone. The breach zone is characterized by destruction of buildings and the highest life safety consequence. Yonkman describes this area as having velocities greater than 6 feet per second and the product of depth and velocity greater than 22 ft^2 per second. For the Sutter Basin Feasibility study, velocities within 1000 feet of the breach were assumed to be great

enough to destroy buildings. This distance is based on evaluation of the 1955 levee breach which showed structures knocked off their foundations.

(2) Zone with rapidly rising water. This zone is characterized by rapidly changing velocity and depth. Model results indicate velocities of less than 3 feet per second within a few thousand feet from a levee breach.

(3) Remaining zone. This zone is characterized by slower onset of flooding. The majority of the study area is defined as the remaining zone. Models of the F9.0R breach indicate velocities of less than 2fps for the remaining portion of the inundation area. Higher velocities are indicated where flows overtop linear features such as the UPRR railroad embankment. Additional locations with higher velocities may occur. However, they would be localized and uncertain.

e. Evacuation Routes. The composite floodplain maps include the location of potential evacuation routes within the Sutter Basin study area. The Sutter County Evacuation and Mass Shelter/Care Plan identify Highways 20, 99 and 113 as the primary evacuation routes in the region. These routes are subject to change since these routes are event-specific and official routes are established by the County Sheriff's office during an emergency. The Butte County Office of Emergency Management does not have published evacuation routes at this time, but anticipates Highways 99, 162 and the Colusa Highway could be used as conditions allow (SBFCA, 2012).

The maps provide an indication of evacuation reliability associated with potential flood depths within the basin. However, the following limitations should be considered when comparing the floodplain maps to the evacuation routes.

(1) Evacuation routes depicted on the maps may be closed due to localized flooding related to interior drainage. During the 1997 flood event, seven different evacuation zones were established over seven days due to constantly changing conditions (SBFCA, 2012). The main evacuation routes used for this flood event were Highway-99 north and Highway-113 south. Highway-20 west and Highway-99 south were used intermittently since all portions of these roads were not accessible at all times during the flood. During the 1955 flood one of the spans of 5th street bridge crossing from Yuba City to Marysville collapsed into the river due to pier scour.

(2) The destination of the evacuation routes are also at risk of flooding.

(3) The FLO-2D model results shown on the maps are based on a grid element size of 1000 feet. Depths shown are an average over the grid element. The model includes the large scale features that impact the general depth and direction of flooding. These large features include levees, railroad embankment and bridges and culverts through the railroad embankment. Small scale topographic features such as drainage ditches, roadway embankments, and roadway culverts are not represented in the model. In addition, small scale topographic variations along roadways (vertical crests and vertical sags) are not represented. As a result, the small scale depressions that can make a roadway impassable are not represented. Whereas the model results may show 0.1 feet of average depth along a roadway alignment, the actual depths could be 3 feet

deep in the smaller topographic depressions. A model depth of 0.1 feet should be used as a likely indicator that a roadway is impassable.

(4) The maps are the composite of multiple breach simulations. The maps depict long term probabilities. However, each flood event would result from different breach locations. The evacuation route during a breach would be highly uncertain. Individual breach inundation maps are provided in Plates 31 though 48.

(5) The maps include representative breach locations and resulting depth fields. Additional levee breach simulations may result in greater depths in some locations.

f. Flood Warning Time. Flood warning time varies throughout the area and is dependent on the source of flooding. The principle sources of flood warnings are advisories by the National Weather Service (NWS) and river stage forecasts by the California Nevada River Forecast Center (CNRFC).

Flood warnings/small river and stream flood warnings are issued by the NWS when flooding of main stem rivers is occurring or imminent (CNRFC, 2013). Main stem river flooding refers to flooding of gauged and forecasted rivers (CNRFC, 2013). The product can also be used to issue Small River and Stream Flood Warnings for smaller rivers/streams which do not have forecast points.

Flash Flood Warnings are issued when flooding is reported; when precipitation capable of causing flooding is observed by radar and/or satellite; when observed rainfall exceeds flash flood guidance or criteria known to cause flooding; or when a dam or levee failure has occurred or is imminent (CNRFC, 2013). A flash flood is defined as a flood caused by heavy or excessive rainfall in a short period of time, and occurring generally within 6 hours of the causative event (CNRFC, 2013).

In addition to the advisories described above, the NWS in coordination with the California Department of Water Resources issues forecasts and guidance for river flows through the CNRFC. In general, river forecasts are based on modeled runoff from observed precipitation, snowmelt estimates, and reservoir operations. The forecast length varies depending on the location. River guidance is based on modeled runoff from forecasted precipitation, snowmelt estimates, and reservoir operations. The forecasts and guidance are issued for a forecast site in a graphical format that compares the future river stage to a monitor stage, flood stage, and danger stage. The combined forecast and guidance are made 5 days into the future.

Flooding from interior drainage sources within the study area is likely to be the result of localized concentrated rainfall. It is assumed these floods would be preceded by a general flood watch issued by the NWS 12 to 24 hours in advance and a flash flood warning 6 hours in advance of the localized flooding.

Flooding from a levee overtopping event along the Feather River would result from a large regional storm event in the Feather, Yuba, and Bear River watersheds. CNRFC river flood forecast points on the Feather River are located at Gridley, Yuba City, Boyds Landing, and

Nicholas. It is assumed that an overtopping flood would be preceded by a flood warning and river guidance issued by the NWS and CNRFC five days in advance. A more accurate warning of potential levee overtopping, based on river forecasts, would likely be made 24 to 36 hours in advance. This estimate was based on a review of the flood guidance plots for December 2005-January2006 flood which indicate an approximate 24 to 36 hour lag between observed rain plus snowmelt in the basin and the peak measured stage at the Feather River near Gridley stream gage forecast point.

Flooding from a levee overtopping event along the Sutter Bypass would result from a large regional storm event in Sacramento River watershed. There are no CNRFC forecast points on the Sutter Bypass. However, the forecast point on the Sacramento River at Fremont Weir represents flood conditions within the Sutter Bypass. It is assumed these floods would be preceded by a flood warning and river guidance issued by the NWS and CNRFC five days in advance. A more accurate warning of potential levee overtopping, based on river forecasts, would likely be made 24 to 36 hours in advance. This estimate was based on a review of the flood guidance plots for the December 2005-January2006 flood which indicate an approximate 24 to 36 hour lag between observed rain plus snowmelt in the basin and the peak measured stage at the Sacramento River at Fremont Weir gage forecast point.

It is estimated that flooding from a geotechnical levee breach would have little to no advance warning (less than 1 hour) and the floodwave would rapidly inundate the adjacent areas. The levee breach that occurred at Shanghai Bend during the December 1955 flood is an indicator of flood warning times associated with geotechnical related failures. The levee failure was preceded by the Governor of the State of California issuing a "Stage of Emergency" on 22 December due to the abnormal and heavy rainfall (Sutter County, 1957). However, the general evacuation order was given approximately 1-hour after the break (Sutter County, 1957).

g. Loss of Life Potential. To evaluate the potential for loss of life, the population density within the study area was compared to the composite floodplain maps. The distribution of population within the study area was based on 2010 census blocks. The population was assigned to single family residences within the census block. The population of the residences within each FLO-2D grid element was then summed. The population within a floodplain was a simple addition of all grid elements with depths greater than a specified depth. A map of the estimated population density throughout the study area is provided in Plate 4.

The population within areas greater than 0 feet, 2 feet, and 15 feet are provided in Tables 28, 29, and 30 respectively.

Table 28.
Population within Alternative SB1 Floodplain
Depths Greater Than 0 Feet

Economic Evaluation Area	Population within ACE Floodplain						
	50% (1/2)	**10% (1/10)**	**4% (1/25)**	**2% (1/50)**	**1% (1/100)**	**0.5% (1/200)**	**0.2% (1/500)**
Town of Sutter	0	0	0	0	0	0	251
Yuba City Urban	0	67351	67368	67368	67368	67368	67368
Biggs Urban	0	19	1452	1452	1452	1452	1763
Gridley Urban	0	0	6379	6379	6379	6379	6379
Live Oak Urban	0	0	8362	8362	8362	8362	8362
Sutter County Rural	1089	4837	6260	6314	6323	6354	6378
Butte County Rural	0	9	4776	4788	4788	4793	4899
Total	1089	72216	94597	94663	94672	94707	95400

Table 29.
Population within Alternative SB1 Floodplain
Depths Greater Than 2 Feet

Economic Evaluation Area	Population within ACE Floodplain						
	50% (1/2)	**10% (1/10)**	**4% (1/25)**	**2% (1/50)**	**1% (1/100)**	**0.5% (1/200)**	**0.2% (1/500)**
Town of Sutter	0	0	0	0	0	0	0
Yuba City Urban	0	57736	63471	64529	64529	66380	67368
Biggs Urban	0	0	1352	1352	1352	1353	1554
Gridley Urban	0	0	1176	1176	1176	1186	5483
Live Oak Urban	0	0	4156	5882	5882	6498	8362
Sutter County Rural	767	4088	4840	5098	5095	5505	6199
Butte County Rural	0	0	2424	2527	2527	2887	3882
Total	767	61824	77418	80564	80561	83809	92847

Table 30.
Population within Alternative SB1 Floodplain
Depths Greater Than 15 Feet

Economic Evaluation Area	Population within ACE Floodplain						
	50% (1/2)	**10% (1/10)**	**4% (1/25)**	**2% (1/50)**	**1% (1/100)**	**0.5% (1/200)**	**0.2% (1/500)**
Town of Sutter	0	0	0	0	0	0	0
Yuba City Urban	0	0	137	137	137	303	934
Biggs Urban	0	0	0	0	0	0	0
Gridley Urban	0	0	0	0	0	0	0
Live Oak Urban	0	0	0	0	0	0	0
Sutter County Rural	0	499	774	944	958	1059	1183
Butte County Rural	0	0	0	0	0	0	0
Total	0	499	911	1080	1095	1362	2117

3.9 Potential Adverse Effects.

a. Induced Flooding. There is no induced flooding associated with the without project condition.

b. Transfer of Flood Risk. There is no transfer of flood risk associated with the without project condition. However, Alternative SB-1 forms the basis for evaluating the transfer of risk for other alternatives. The transfer of flood risk is evaluated by comparing with-project and without-project performance values at index points throughout the system. For purposes of evaluating system impacts, the risk analysis is limited to hydrologic and hydraulic parameters and their uncertainties. This approach is consistent with Section 3.b (2) of the memorandum "Clarification Guidance on the Policy and Procedural Guidance for the Approval of Modifications and Alterations of Corps of Engineers Projects" (USACE, 2008). The performance values associated with hydrologic and hydraulic parameters, and their uncertainties, are provided in Table 31.

Table 31
Project Performance at Simulated Levee Breach Locations
Hydrologic and Hydraulic Parameters Only

Simulated Breach		Annual Exceedance Probability		Long Term Probability of Failure			Flood Risk Management Assurance by Event Flood Frequency							
Label	River Mile	Median	Exp.	10 Years	30 Years	50 Years	50% ACE	10% ACE	4% ACE	2% ACE	1% ACE	0.5% ACE	0.2% ACE
Feather River														
F9.0R	57.17	0.0020	0.0023	0.0233	0.0683	0.1112	0.9999	0.9999	0.9949	0.9915	0.9726	0.8551	0.6390
F8.0R	50.20	0.0001	0.0023	0.0225	0.0659	0.1075	0.9999	0.9999	0.9949	0.9915	0.9726	0.8551	0.6390
F7.0R	41.55	0.0022	0.0022	0.0220	0.0646	0.1054	0.9999	0.9999	0.9999	0.9999	0.9895	0.8576	0.5427
F6.0R	34.07	0.0022	0.0022	0.0215	0.0630	0.1028	0.9999	0.9999	0.9999	0.9999	0.9901	0.8620	0.5547
F5.0R	28.25	0.0022	0.0022	0.0215	0.0630	0.1028	0.9999	0.9999	0.9999	0.9999	0.9901	0.8620	0.5548
F4.5R	26.00	0.0022	0.0023	0.0224	0.0656	0.1070	0.9999	0.9999	0.9999	0.9999	0.9876	0.8508	0.5434
F4.4R	25.99	0.0022	0.0023	0.0224	0.0656	0.1070	0.9999	0.9999	0.9999	0.9999	0.9876	0.8508	0.5434
F4.1R	17.00	0.0026	0.0032	0.0315	0.0916	0.1479	0.9999	0.9999	0.9999	0.9995	0.9728	0.7665	0.3773
F4.0R	16.99	0.0026	0.0032	0.0315	0.0916	0.1479	0.9999	0.9999	0.9999	0.9995	0.9728	0.7665	0.3773
F3.0R	10.50	0.0024	0.0027	0.0267	0.0781	0.1267	0.9999	0.9999	0.9999	0.9992	0.9744	0.8030	0.4813
Sutter Bypass														
S5.0L	88.04	0.0027	0.0037	0.0362	0.1048	0.1686	0.9999	0.9999	0.9995	0.9874	0.9087	0.7126	0.4666
S4.0L	82.45	0.0029	0.0040	0.0390	0.1126	0.1805	0.9999	0.9999	0.9994	0.9857	0.8992	0.6903	0.4306
S3.0L	77.05	0.0036	0.0036	0.0520	0.1481	0.2344	0.9999	0.9999	0.9977	0.9713	0.8483	0.6001	0.3058
Wadsworth Canal														
W3.0R	4.54	0.0065	0.0086	0.0826	0.2279	0.3501	0.9999	0.9995	0.9951	0.9338	0.705	0.3791	0.0786
W2.0R	2.42	0.0048	0.0055	0.0394	0.1137	0.1823	0.9999	0.9995	0.9995	0.9995	0.9946	0.7118	0.0904
W2.0L	2.42	0.0036	0.0048	0.0540	0.1534	0.2424	0.9999	0.9995	0.9995	0.9984	0.9521	0.4586	0.0181
Cherokee Canal														
CC2.0L	13.34	0.1205	0.1576	0.8200	0.9942	0.9998	0.9999	0.3986	0.1293	0.0474	0.0177	0.0077	0.0018
CC1.0L	11.4	0.1205	0.1576	0.8200	0.9942	0.9998	0.9999	0.3986	0.1293	0.0474	0.0177	0.0077	0.0018

3.10 California State Urban Levee Design Criteria

A local sponsor objective is to achieve the California State Urban Levee Design Criteria (ULDC). The ULDC criteria are described in the DWR report "Urban Levee Design Criteria, May 2012. The purpose of the ULDC is to provide engineering criteria and guidance for civil engineers to follow in meeting the requirements of California's Government Code Sections 65865.5, 65962, and 66474.5 with respect to findings that levees and floodwalls in the Sacramento-San Joaquin Valley provide protection against a flood that has a 1-in-200 chance of occurring in any given year, and to offer this same guidance to civil engineers working on levees and floodwalls anywhere in California (DWR, 2012). Two options are offered for determining if a levee meets the urban and urbanizing area levee system design.

The freeboard approach requires 3 feet of freeboard above the mean 0.5% (1/200) ACE flood event. The risk and uncertainty approach allows for a lesser amount of freeboard if a high level of assurance can be demonstrated. For assurance less than 90% the levee does not pass criteria 2) For assurance between 90 and 95% levee must have minimum of 3 feet of freeboard to pass criteria. 3) For assurance greater than 95% levee must have minimum of 2 feet of freeboard to pass criteria.

Both ULDC approaches require that water surface profiles do not account for overtopping in urban areas for the 0.5% (1/200) ACE event. An evaluation of the Sutter Basin study area indicated no overtopping occurs for the 0.5% (1/200) ACE event. Therefore, the hydraulic model results were applicable for the ULDC analysis. Both ULDC approaches require that additional freeboard be provided if the wind wave run-up from a 1.3% ACE wind event would exceed the top of levee. Both ULDC approaches also require minimum geotechnical standards.

Based on a review of the ULDC criteria, none of the levee reaches would meet the ULDC criteria without geotechnical remediation.

4.0 Alternative SB-7 (Sunset Weir to Laurel Ave)

4.1 General Design Features

a. Levees. This project would involve fixing the Feather River levees to meet current USACE design standards from Sunset Weir to Laurel Ave. The levee height would be based on the 1957 design profile or the existing profile, whichever is higher. In no cases would the levee be raised above these profiles.

b. Interior Drainage Facilities. The project would involve the replacement of gravity drainage culverts within the reach. All replacement culverts would remain the same capacity as the without project conditions.

c. Operation and Maintenance. The project will be maintained to meet current design standards. The project will rely on one gate type closure structure at the UPRR railroad bridge crossing (RM 29.8).

4.2 Hydrology.

The hydrology associated with Alternative SB-7 is identical to Alternative SB-1 (without project conditions).

4.3 Hydraulic Models

Hydraulic models associated with Alternative SB-7 are identical to Alternative SB-1 (without project conditions). The alternative does not include any features that change the hydraulic conditions or geometry.

4.4 Hydraulic Model Results.

Hydraulic model results associated with Alternative SB-7 are identical to Alternative SB-1 (without project conditions).

4.5 Hydraulic Design.

a. Levee Height. This project would involve fixing the Feather River levees to meet current USACE design standards from Thermalito Afterbay to Laurel Avenue. The levee height would be based on the 1957 design profile or the existing profile, whichever is higher. In no cases would the levee be raised above these profiles.

b. Closure Structures. A gate type closure structure is specified where the UPRR crosses the levee embankment at River Mile 29.8. This location is the lowest point along the levee and the performance of project depends on the closure structure operating correctly. If this structure is not operated correctly the levee could breach due to overtopping. This would result in rapid inundation of Yuba City. This is a highly populated area and a failure would have high life safety consequences. To further increase the robustness of the levee, this location would be made more resistant to overtopping.

c. Levee Superiority. The definition of levee superiority per EC 1110-2-6066 (*Design of I-Walls*, 31 October 2010) is the increment of additional height added to a flood risk management system to increase the likelihood that when the design event is exceeded, controlled flooding will occur at the design overtopping section. Since alternative SB-7 is based on an existing levee profile, the design top of levee was reviewed relative to the modeled mean water surface profiles to determine the likely initial overtopping location. A single initial overtopping location was determined within the SB-7 project reach. It is estimated that the initial overtopping would likely occur between River Miles 19 and 20 (FRWLP Station 547+00 to 604+60). This location is a non-urbanized area and initial overtopping is estimated to occur between the mean 0.5% (1/200) ACE and 0.2% (1/500) ACE events. Within this 1-mile reach, the landward side of the levee will be covered with anchored High Performance Turf Reinforced Mat (HPTRM). This design will increase the erosion resistance of the levee and allow for more controlled failure of the levee due to overtopping.

d. Erosion Protection. Erosion protection was not specified within the design reach.

e. Interior Drainage Facilities. If replacement is required to meet USACE design standards, the existing drainage features will be replaced with the same hydraulic capacity.

4.6 Wind Wave Analysis

Wind wave runup and setup associated with Alternative SB-7 is identical to Alternative SB-1 (without project conditions).

4.7 Sedimentation and Channel Stability

Sedimentation and Channel Stability associated with Alternative SB-7 is identical to Alternative SB-1 (without project conditions).

4.8 Flood Risk.

Flood risk would be reduced by Alternative SB-7 by reduction of the geotechnical fragility within the project reach.

a. Levee Assurance. Levee assurance values within reaches modified by the project were recomputed assuming no failure until overtopping. Detailed with-project fragility curves were not used to conduct the with-project analysis. An economic sensitivity analysis was conducted to evaluate this simplified with-project fragility assumption and it was determined it would have insignificant impacts on the results. All other inputs to calculate assurance were identical to Alternative SB-1, the without project condition. The assurance values are provided in Table 32.

b. Composite Floodplains. Maps showing composite floodplains were developed to demonstrate FRM reliability for Alternative SB-7. The composite floodplains are provided in Plates 57 to 64. All maps include the natural (non-leveed) flood inundation depths. Table 32 provides the assurance values used to determine if a simulated breach was included in the composite floodplain map.

d. Flood Velocities. Flood velocities for a levee beach would be identical as alternative SB-1.

Table 32
Assurance at Simulated Levee Breach Locations, Alternative SB-7

Simulated Breach		Annual Exceedance Probability		Long Term Risk			Flood Risk Management Assurance by Event Flood Frequency (Breach included in floodplain map if shaded)						
Label	River Mile	Median	Exp.	10 Years	30 Years	50 Years	50% ACE	10% ACE	4% ACE	2% ACE	1% ACE	0.5% ACE	0.2% ACE
Feather River													
F9.0R	57.17	0.0696	0.0769	0.5506	0.9092	0.9817	0.9909	0.8187	0.6499	0.6087	0.5777	0.4781	0.331
F8.0R	50.20	0.0686	0.0768	0.5504	0.9091	0.9816	0.9909	0.8187	0.6499	0.6087	0.5777	0.4781	0.331
F7.0R	41.55	0.0203	0.0238	0.2138	0.5140	0.6996	0.9999	0.9299	0.7965	0.7586	0.7209	0.5657	0.298
F6.0R	34.07	0.0022	0.0022	0.0215	0.0630	0.1028	0.9999	0.9999	0.9999	0.9999	0.9901	0.8620	0.5547
F5.0R	28.25	0.0022	0.0022	0.0215	0.0630	0.1028	0.9999	0.9999	0.9999	0.9999	0.9901	0.8620	0.5548
F4.5R	26.00	0.0022	0.0023	0.0224	0.0656	0.1070	0.9999	0.9999	0.9999	0.9999	0.9876	0.8508	0.5434
F4.4R	25.99	0.0022	0.0023	0.0224	0.0656	0.1070	0.9999	0.9999	0.9999	0.9999	0.9876	0.8508	0.5434
F4.1R	17.00	0.0026	0.0032	0.0315	0.0916	0.1479	0.9999	0.9999	0.9999	0.9995	0.9728	0.7665	0.3773
F4.0R	16.99	0.0026	0.0032	0.0315	0.0916	0.1479	0.9999	0.9999	0.9999	0.9995	0.9728	0.7665	0.3773
F3.0R	10.50	0.0167	0.0192	0.1766	0.4418	0.6216	0.9999	0.9443	0.9171	0.889	0.8447	0.6847	0.4057
Sutter Bypass													
S5.0L	88.04	0.2184	0.2331	0.9297	0.9997	0.9999	0.8232	0.5684	0.4267	0.3803	0.2991	0.1896	0.0827
S4.0L	82.45	0.4468	0.5156	0.9993	0.9999	0.9999	0.5362	0.3336	0.3257	0.2956	0.2223	0.1391	0.0631
S3.0L	77.05	0.1945	0.2104	0.9058	0.9992	0.9999	0.8101	0.6612	0.635	0.6009	0.5021	0.3426	0.1654
Wadsworth Canal													
W3.0R	4.54	0.0065	0.0086	0.0826	0.2279	0.3501	0.9999	0.9995	0.9951	0.9338	0.705	0.3791	0.0786
W2.0R	2.42	0.3590	0.3577	0.9880	0.9999	0.9999	0.6394	0.3611	0.239	0.2263	0.1884	0.0874	0.0074
W2.0L	2.42	0.1137	0.1157	0.7075	0.9750	0.9979	0.9583	0.7575	0.5626	0.4783	0.3363	0.1392	0.0056
Cherokee Canal													
CC2.0L	13.34	0.2616	0.2803	0.9627	0.9999	0.9999	0.8618	0.3115	0.1005	0.0373	0.0142	0.0061	0.0015
CC1.0L	11.4	0.2616	0.2803	0.9627	0.9999	0.9999	0.8618	0.3115	0.1005	0.0373	0.0142	0.0061	0.0015

Notes: Assurance based on existing top of levee or 1957 design top of levee, whichever is higher within the reach. Assurance accounts for stage uncertainty, hydrologic uncertainty, and geotechnical uncertainty.
Index points within the Alternative SB-7 project reach shown in Bold Italics

d. Evacuation Routes. Evacuation routes for alternative SB-7 are shown on the composite floodplain maps. Relative to Alternative SB-1, the project increases the reliability of the evacuation route to Marysville.

e. Flood Warning Time. A description of flood warning time is provided in Alternative SB-1. Alternative SB-7 will result in a significant increase in warning time to the population within Yuba City because the probability of flooding from a geotechnical type failure (1-hour warning time) would be reduced and the warning time for overtopping type failures are significantly longer (24 to 36 hours).

f. Loss of Life Potential. To evaluate the potential for loss of life, the population density within the study area was compared to the composite floodplain maps of alternative SB-7. The distribution of population within the study area was based on 2010 census blocks. A map of the estimated population density throughout the study area is provided in Plate 4. The population within areas greater than 0 feet, 2 feet, and 15 feet are provided in Tables 33, 34, and 35 respectively.

Table 33.
Population within Alternative SB-7 Floodplain
Depths Greater Than 0 Feet

Economic Evaluation Area	Population within ACE Floodplain						
	50% (1/2)	**10% (1/10)**	**4% (1/25)**	**2% (1/50)**	**1% (1/100)**	**0.5% (1/200)**	**0.2% (1/500)**
Town of Sutter	0	0	0	0	0	0	251
Yuba City Urban	0	43	6194	12519	14429	67368	67368
Biggs Urban	0	19	1452	1452	1452	1452	1763
Gridley Urban	0	0	6379	6379	6379	6379	6379
Live Oak Urban	0	0	8362	8362	8362	8362	8362
Sutter County Rural	1089	1718	4788	5742	5867	6354	6378
Butte County Rural	0	9	4776	4788	4788	4793	4899
Total	1089	1789	31951	39242	41276	94707	95400

Table 34.
Population within Alternative SB-7 Floodplain
Depths Greater Than 2 Feet

Economic Evaluation Area	Population within ACE Floodplain						
	50% (1/2)	**10% (1/10)**	**4% (1/25)**	**2% (1/50)**	**1% (1/100)**	**0.5% (1/200)**	**0.2% (1/500)**
Town of Sutter	0	0	0	0	0	0	0
Yuba City Urban	0	0	16	699	976	66380	67368
Biggs Urban	0	0	1352	1352	1352	1353	1554
Gridley Urban	0	0	1176	1176	1176	1186	5483
Live Oak Urban	0	0	4156	5882	5882	6498	8362
Sutter County Rural	767	1478	2073	2930	3267	5505	6199
Butte County Rural	0	0	2424	2527	2527	2887	3882
Total	767	1478	11196	14567	15180	83809	92847

Table 35.
Population within Alternative SB-7 Floodplain
Depths Greater Than 15 Feet

Economic Evaluation Area	Population within ACE Floodplain						
	50% (1/2)	**10% (1/10)**	**4% (1/25)**	**2% (1/50)**	**1% (1/100)**	**0.5% (1/200)**	**0.2% (1/500)**
Town of Sutter	0	0	0	0	0	0	0
Yuba City Urban	0	0	0	0	0	303	934
Biggs Urban	0	0	0	0	0	0	0
Gridley Urban	0	0	0	0	0	0	0
Live Oak Urban	0	0	0	0	0	0	0
Sutter County Rural	0	0	4	231	303	1059	1183
Butte County Rural	0	0	0	0	0	0	0
Total	0	0	4	231	303	1362	2117

4.9 Potential Adverse Effects.

a. Induced Flooding. The hydraulic features associated with Alternative SB-7 are identical to Alternative SB-1. Therefore, there is no induced flooding associated with Alternative SB-7.

b. Transfer of Flood Risk. The hydraulic features associated with Alternative SB-7 are identical to Alternative SB-1. Therefore, there is no induced flooding associated with Alternative SB-7.

4.10 California State Urban Levee Design Criteria

Based on a review of the ULDC criteria, none of the levee reaches only the reaches associated with breaches F4.0R, F4.1R, F4.4R, F4.5R, F5.0R would meet the DWR ULDC criteria. As a result only the Yuba City Urban area would meet the ULDC requirements.

5.0 Alternative SB-8 (Thermalito to Laurel Avenue)

5.1 General Design Features

a. Levees. This project would involve fixing the Feather River levees to meet current USACE design standards from Thermalito Afterbay to Laurel Avenue. The levee height would be based on the 1957 design profile or the existing profile, whichever is higher. In no cases would the levee be raised above these profiles. Within three reaches, the levee will be shifted 20 feet towards the river. This was required to provide an access road on the landward side of the levee toe. Additional details are discussed in the hydraulic design section below.

b. Interior Drainage Facilities. The project would involve the replacement of gravity drainage culverts within the reach. Five of the gravity drainage culverts will be removed because they are no longer used for drainage and one culvert will be downsized. Additional details are discussed in the hydraulic design section below.

c. Operation and Maintenance. The project will be maintained to meet current design standards. The project will rely on one flood gate closure structure at the UPRR railroad bridge crossing.

5.2 Hydrology.

The hydrology associated with Alternative SB-8 is identical to Alternative SB-1 (without project conditions).

5.3 Hydraulic Models

Hydraulic models were revised to incorporate the 20 foot riverward shift in the levee along three reaches. The shift in the levee alignment was necessary to provide an access road adjacent to an existing canal located along the landward toe. The upstream reach is 2.3 miles long and extends from RM 45.5 (FRWL station 1675+00) to RM 47.55 (FRWL station 1753+00). The middle reach is 0.25 miles long and extends from RM 44.6 (FRWL Station 1610+00) to RM 44.8 (FRWL Station 1623+00). The lower reach is 0.28 miles long and extends from RM 38.8 (FRWL Station 1434+00) to RM 39.1 (FRWL Station 1449+00). All other model features are the same as the SB-1 alternative.

5.4 Hydraulic Model Results.

The hydraulic model created for Alternative SB-8 computed the same water surface profiles as Alternative SB-1. Within the three reaches where the levee will be shifted 20 feet riverward, the channel cross section width is over 5000 feet and this was found to have no measureable impact on the water surface throughout the model domain. Therefore, the hydraulic model results provided for Alternative SB-1 are applicable to SB-8.

5.5 Hydraulic Design.

a. Levee Height. This project would involve fixing the Feather River levees to meet current USACE design standards from Thermalito Afterbay to Laurel Avenue. The levee height would be based on the 1957 design profile or the existing profile, whichever is higher. In no cases would the levee be raised above these profiles.

b. Closure Structures. A gate type closure structure is specified where the UPRR crosses the levee embankment at River Mile 29.8. This location is the lowest point along the levee and the performance of project depends on the closure structure operating correctly. If this structure is not operated correctly the levee could breach due to overtopping. This would result in rapid inundation of Yuba City. This is a highly populated area and a failure would have high life safety consequences. To further increase the robustness of the levee, this location would be made more resistant to overtopping.

c. Levee Superiority. The definition of levee superiority per EC 1110-2-6066 (*Design of I-Walls,* 31 October 2010) is the increment of additional height added to a flood risk management system to increase the likelihood that when the design event is exceeded, controlled flooding will occur at the design overtopping section. Since alternative SB-8 is based on an existing levee profile, the design top of levee was reviewed relative to the modeled mean water surface profiles to determine likely initial overtopping locations. Alternative SB-8 extends upstream and downstream of the Yuba River tributary. Initial overtopping locations were identified upstream and downstream of confluence to account for the uncertainty in the aerial centering of storm events.

It is estimated that the initial overtopping location upstream of the Yuba River confluence would occur between River Miles 43.5 and 45.5 (FRWLP Station 1582+00 to 1601+00). This location is a non-urbanized area and initial overtopping is estimated to occur between the mean 0.5% (1/200) ACE and 0.2% (1/200) ACE events.

It is estimated that the initial overtopping location downstream of the Yuba River would occur between River Miles 19 and 20 (FRWLP Station 547+00 to 604+60). This location is a non-urbanized area and initial overtopping is estimated to occur between the mean 0.5% (1/200) ACE and 0.2% (1/200) ACE events. This is identical to the reach identified for the SB7 alternative.

Within both 1-mile reaches, the landward side of the levee will be covered with anchored High Performance Turf Reinforced Mat (HPTRM). This design will increase the erosion resistance of the levee and allow for more controlled failure of the levee due to overtopping.

d. Erosion Protection. Erosion protection was not specified within the design reach.

e. Interior Drainage Facilities. All drainage features would be replaced with the same capacity except at six locations described in Table 36. Five of the facilities appear to provide no interior drainage function and one location appears to be oversized. Each of the six sites was visited by SBFCA's engineering consultant, PBI, and adjacent land owners were reviewed. The results of the analysis are described in a technical memorandum to the Sutter Butte Flood Control Agency titled, Culvert Removal Analysis for the Feather River West Levee Improvement Project, 17 August, 2012.

Table 36
Proposed Culvert Modifications, Alternative SB-8

River Mile	FRWLP Station	Culvert Size	Notes
44.90	1639+00	2-24"	Remove Culvert, Culvert inlet was filled with soil with no obvious signs of a drainage path leading to the culvert
48.00	1785+24	1-24"	Remove Culvert, Culvert did not appear to be used with no signs of a drainage path leading to the culvert
51.20	1961+03	2-60"	Reduce Culvert Size, Culvert appeared to be oversized. Recommend reducing size to 1-36"
57.05	2239+66	1-24"	Remove Culvert, No culvert inlet was found.
57.10	2245+52	1-24"	Remove Culvert, Culvert inlet was filled with soil with no obvious signs of a drainage path leading to the culvert
57.15	2256+94	1-24"	Remove Culvert, Culvert inlet was nearly buried. Culvert is located near another culvert. Nearby culvert should provide adequate capacity.

5.6 Wind Wave Analysis.

Wind wave runup and setup associated with Alternative SB-8 is identical to Alternative SB-1 (without project conditions).

5.7 Sedimentation and Channel Stability

Sedimentation and Channel Stability associated with Alternative SB-8 is identical to Alternative SB-1 (without project conditions).

5.8 Flood Risk.

Flood risk would be reduced by Alternative SB-8 by reduction of the geotechnical fragility within the reach.

a. Levee Assurance. Levee assurance values within reaches modified by the project were recomputed assuming no failure until overtopping. Detailed with-project fragility curves were not used to conduct the with-project analysis. An economic sensitivity analysis was conducted to evaluate this simplified with-project fragility assumption and it was determined it would have insignificant impacts on the results. All other inputs to calculate assurance were identical to Alternative SB-1, the without project condition.

b. Composite Floodplains. Maps showing composite floodplains were developed to demonstrate FRM reliability for Alternative SB-8. The composite floodplains are provided in Plates 65 through 71. All maps include the natural (non-leveed) flood inundation depths. Table 37 provides the assurance values used to determine if a simulated breach was included in the floodplain map.

Table 37
Project Performance at Simulated Levee Breach Locations, Alternative SB-8

Simulated Breach		Annual Exceedance Probability		Long Term Risk			Flood Risk Management Assurance by Event Flood Frequency (Breach included in floodplain map if shaded)						
Label	River Mile	Median	Exp.	10 Years	30 Years	50 Years	50% ACE	10% ACE	4% ACE	2% ACE	1% ACE	0.5% ACE	0.2% ACE
Feather River													
F9.0R	57.17	0.0020	0.0023	0.0233	0.0683	0.1112	0.9999	0.9999	0.9949	0.9915	0.9726	0.8551	0.6390
F8.0R	50.20	0.0001	0.0023	0.0225	0.0659	0.1075	0.9999	0.9999	0.9949	0.9915	0.9726	0.8551	0.6390
F7.0R	41.55	0.0022	0.0022	0.0220	0.0646	0.1054	0.9999	0.9999	0.9999	0.9999	0.9895	0.8576	0.5427
F6.0R	34.07	0.0022	0.0022	0.0215	0.0630	0.1028	0.9999	0.9999	0.9999	0.9999	0.9901	0.8620	0.5547
F5.0R	28.25	0.0022	0.0022	0.0215	0.0630	0.1028	0.9999	0.9999	0.9999	0.9999	0.9901	0.8620	0.5548
F4.5R	26.00	0.0022	0.0023	0.0224	0.0656	0.1070	0.9999	0.9999	0.9999	0.9999	0.9876	0.8508	0.5434
F4.4R	25.99	0.0022	0.0023	0.0224	0.0656	0.1070	0.9999	0.9999	0.9999	0.9999	0.9876	0.8508	0.5434
F4.1R	17.00	0.0026	0.0032	0.0315	0.0916	0.1479	0.9999	0.9999	0.9999	0.9995	0.9728	0.7665	0.3773
F4.0R	16.99	0.0026	0.0032	0.0315	0.0916	0.1479	0.9999	0.9999	0.9999	0.9995	0.9728	0.7665	0.3773
F3.0R	10.50	0.0167	0.0192	0.1766	0.4418	0.6216	0.9999	0.9443	0.9171	0.8890	0.8447	0.6847	0.4057
Sutter Bypass													
S5.0L	88.04	0.2184	0.2331	0.9297	0.9997	0.9999	0.8232	0.5684	0.4267	0.3803	0.2991	0.1896	0.0827
S4.0L	82.45	0.4468	0.5156	0.9993	0.9999	0.9999	0.5362	0.3336	0.3257	0.2956	0.2223	0.1391	0.0631
S3.0L	77.05	0.1945	0.2104	0.9058	0.9992	0.9999	0.8101	0.6612	0.635	0.6009	0.5021	0.3426	0.1654
Wadsworth Canal													
W3.0R	4.54	0.0065	0.0086	0.0826	0.2279	0.3501	0.9999	0.9995	0.9951	0.9338	0.705	0.3791	0.0786
W2.0R	2.42	0.3590	0.3577	0.9880	0.9999	0.9999	0.6394	0.3611	0.239	0.2263	0.1884	0.0874	0.0074
W2.0L	2.42	0.1137	0.1157	0.7075	0.9750	0.9979	0.9583	0.7575	0.5626	0.4783	0.3363	0.1392	0.0056
Cherokee Canal													
CC2.0L	13.34	0.2616	0.2803	0.9627	0.9999	0.9999	0.8618	0.3115	0.1005	0.0373	0.0142	0.0061	0.0015
CC1.0L	11.4	0.2616	0.2803	0.9627	0.9999	0.9999	0.8618	0.3115	0.1005	0.0373	0.0142	0.0061	0.0015

Notes: Assurance based on existing top of levee or 1957 design top of levee, whichever is higher within the reach. Assurance accounts for stage uncertainty, hydrologic uncertainty, and geotechnical uncertainty.
Index points within the Alternative SB-8 project reach shown in Bold Italics

c. Flood Velocities. Flood velocities for a levee beach would be identical as alternative SB-1.

d. Evacuation Routes. Evacuation routes for alternative SB-8 are shown on the composite floodplain maps. Relative to Alternative SB-1, the project increases the reliability of the evacuation routes for Marysville, Biggs, Gridley, and Live Oak.

e. Flood Warning Time. A description of flood warning time is provided in Alternative SB-1. Alternative SB-8 will result in a significant increase in warning time to the population within Yuba City, Biggs, Gridley and Live Oak because the probability of flooding from a geotechnical type failure (1-hour warning time) would be reduced and the warning time for overtopping type failures are significantly longer (24 to 36 hours).

f. Loss of Life Potential. To evaluate the potential for loss of life, the population density within the study area was compared to the composite floodplain maps of alternative SB-8. The distribution of population within the study area was based on 2010 census blocks. A map of the estimated population density throughout the study area is provided in Plate 4. The population within areas greater than 0 feet, 2 feet, and 15 feet are provided in Tables 39, 40, and 41 respectively.

Table 38.
Population within Alternative SB8 Floodplain
Depths Greater Than 0 Feet

Economic Evaluation Area	Population within ACE Floodplain						
	50% (1/2)	**10% (1/10)**	**4% (1/25)**	**2% (1/50)**	**1% (1/100)**	**0.5% (1/200)**	**0.2% (1/500)**
Town of Sutter	0	0	0	0	0	0	251
Yuba City Urban	0	43	255	4923	6480	67368	67368
Biggs Urban	0	19	19	19	19	1452	1763
Gridley Urban	0	0	0	0	0	6379	6379
Live Oak Urban	0	0	0	0	0	8362	8362
Sutter County Rural	1089	1718	2110	3036	3269	6354	6378
Butte County Rural	0	9	9	9	18	4793	4899
Total	1089	1789	2393	7987	9786	94707	95400

Table 39.
Population within Alternative SB8 Floodplain
Depths Greater Than 2 Feet

Economic Evaluation Area	Population within ACE Floodplain						
	50% (1/2)	**10% (1/10)**	**4% (1/25)**	**2% (1/50)**	**1% (1/100)**	**0.5% (1/200)**	**0.2% (1/500)**
Town of Sutter	0	0	0	0	0	0	0
Yuba City Urban	0	0	16	417	665	66380	67368
Biggs Urban	0	0	0	0	0	1353	1554
Gridley Urban	0	0	0	0	0	1186	5483
Live Oak Urban	0	0	0	0	0	6498	8362
Sutter County Rural	767	1478	1700	2368	2704	5505	6199
Butte County Rural	0	0	0	0	0	2887	3882
Total	767	1478	1716	2785	3369	83809	92847

Table 40.
Population within Alternative SB8 Floodplain
Depths Greater Than 15 Feet

Economic Evaluation Area	Population within ACE Floodplain						
	50% (1/2)	**10% (1/10)**	**4% (1/25)**	**2% (1/50)**	**1% (1/100)**	**0.5% (1/200)**	**0.2% (1/500)**
Town of Sutter	0	0	0	0	0	0	0
Yuba City Urban	0	0	0	0	0	303	934
Biggs Urban	0	0	0	0	0	0	0
Gridley Urban	0	0	0	0	0	0	0
Live Oak Urban	0	0	0	0	0	0	0
Sutter County Rural	0	0	4	231	303	1059	1183
Butte County Rural	0	0	0	0	0	0	0
Total	0	0	4	231	303	1362	2117

5.9 Potential Adverse Effects.

a. Induced Flooding. The hydraulic features associated with Alternative SB-8 are nearly identical to Alternative SB-1. The hydraulic model created for Alternative SB-8 computed the same water surface profiles as Alternative SB-1. Therefore, there is no induced flooding.

b. Transfer of Flood Risk. Analysis of the alternative found no transfer of flood risk. The hydraulic model created for Alternative SB-8 computed the same water surface profiles as Alternative SB-1. Within the three reaches where the levee will be shifted 20 feet riverward, the channel cross section width is over 5000 feet and this was found to have no measureable impact on the water surface throughout the model domain.

5.10 California State Urban Levee Design Criteria

Based on a review of the ULDC criteria, none of the levee reaches only the reaches associated with breaches F4.0R, F4.1R, F4.4R, F4.5R, F5.0R, F6.0R, F7.0R, F8.0R, and F9.0R would meet the DWR ULDC criteria. As a result the area north of Yuba City Urban area would meet the ULDC requirements but the southern portion of the basin below yuba city would not meet the ULDC criteria.

6.0 SUMMARY

This report describes hydraulic, sedimentation, and operations and maintenance analyses performed for the final alternatives of the Sutter Basin Feasibility Study. Analyses were performed for without-project and two project alternative conditions. The report provides an update of the previous analysis of the without-project conditions.

The study is focused on Sutter Basin Feasibility Study area. Composite floodplain delineations are provided for 50% (1/2) ACE, 10% (1/10) ACE, 4% (1/25) ACE, 2% (1/50) ACE, 1% (1/100) ACE, 0.5% (1/200) ACE, and 0.2% (1/500) ACE events for the existing and alternative conditions.

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ATTACHEMENT A

Memorandum for File:

Sutter Basin Pilot Feasibility Study,

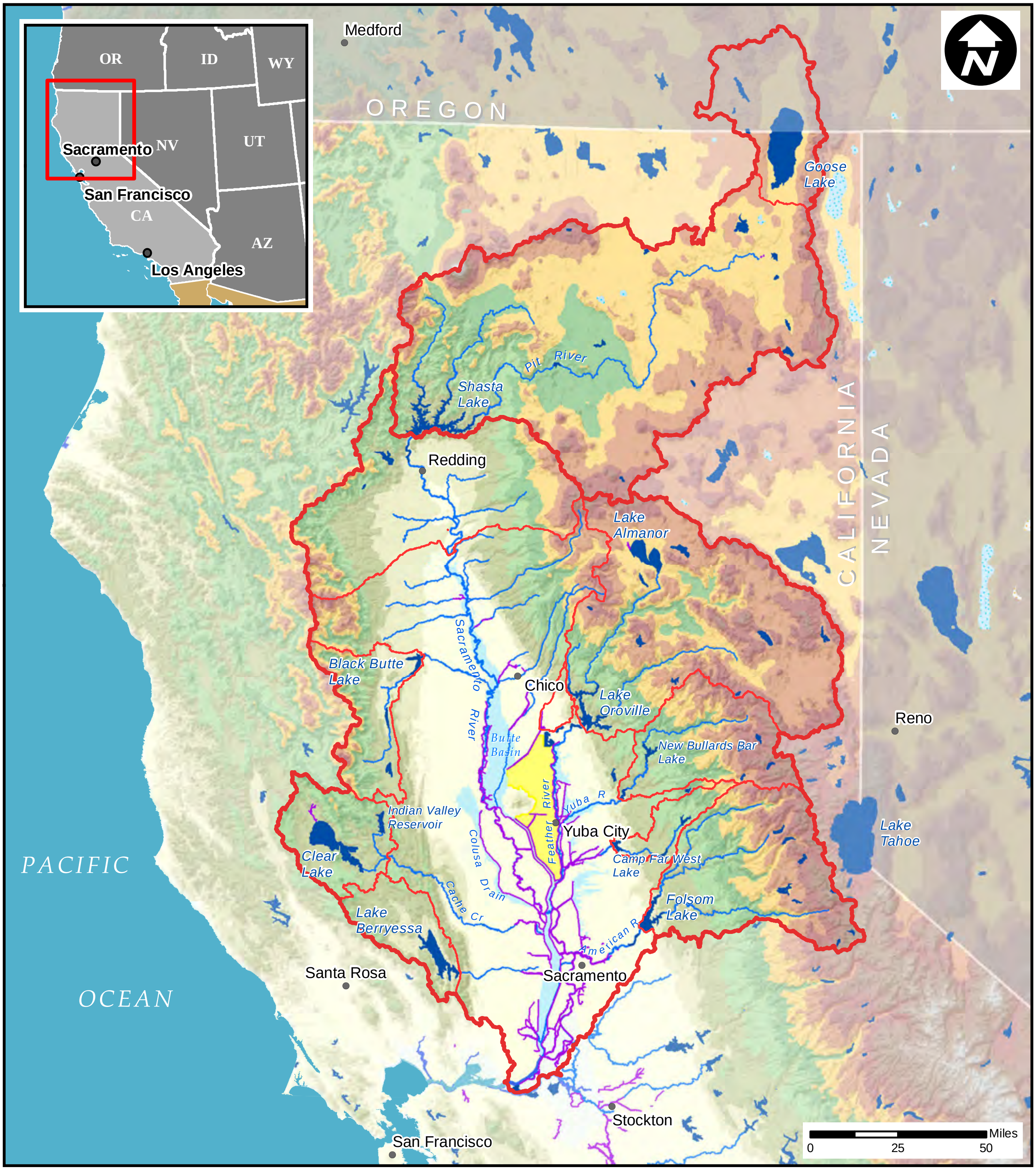
Hydraulic Analysis of Refined Alternatives

8 June 2012

ATTACHMENT B

Final Geotechnical Fragility Curves

February 2013.



Legend

Study Area Extent

Sacramento Basin

Watershed Boundaries

Designated Floodways

Lake or Reservoir

River or Stream

Federal Levees

City

SUTTER BASIN PILOT FEASIBILITY STUDY
SUTTER BASIN, CALIFORNIA

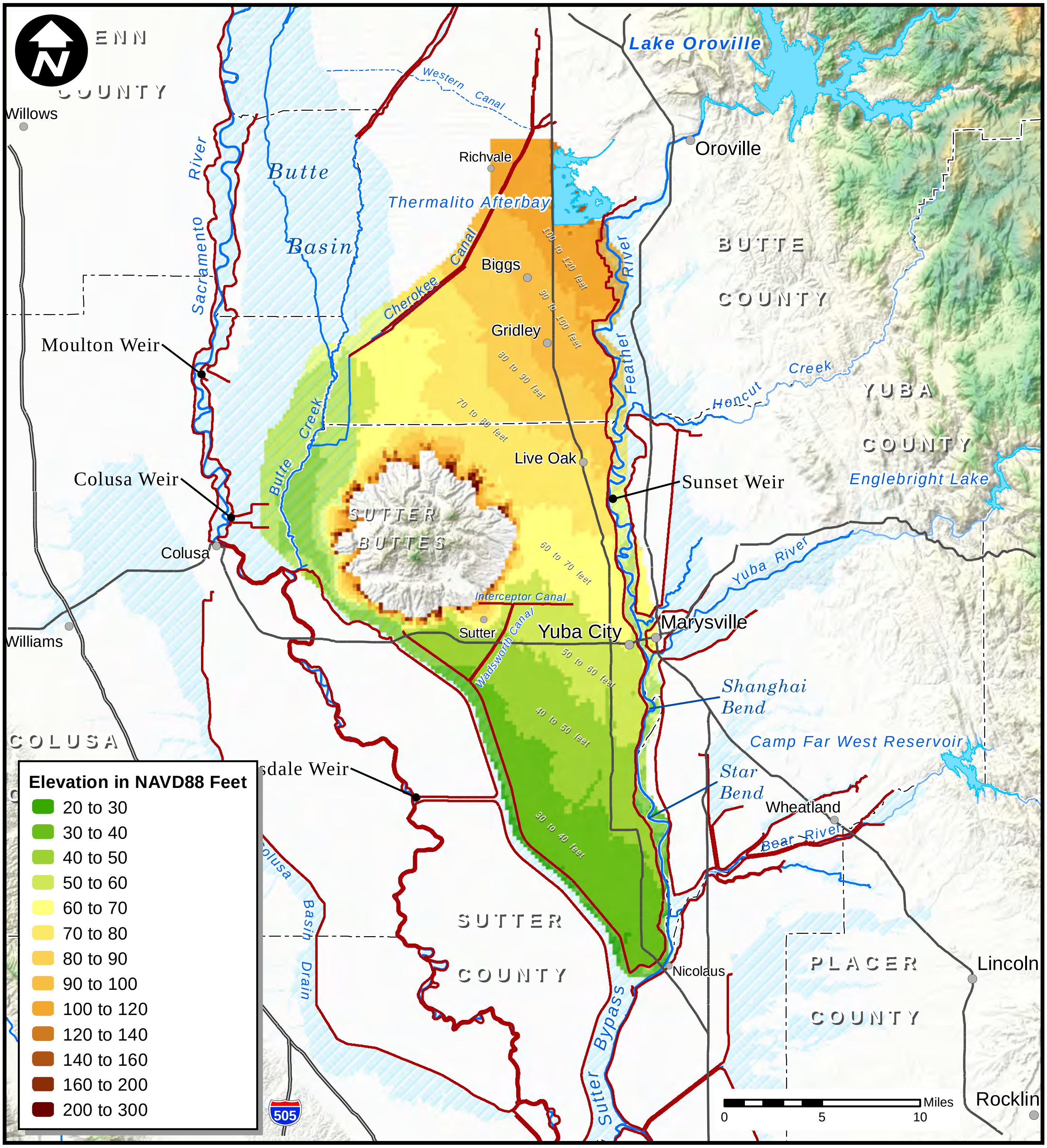
SACRAMENTO RIVER WATERSHED

U.S. ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT

Prepared by Jim Mars

FEB 2013

PLATE 1



Legend

Designated Floodways

Lake or Reservoir

River or Stream

Federal Levee

County Boundary

City or Town

SUTTER BASIN PILOT FEASIBILITY STUDY
SUTTER BASIN, CALIFORNIA

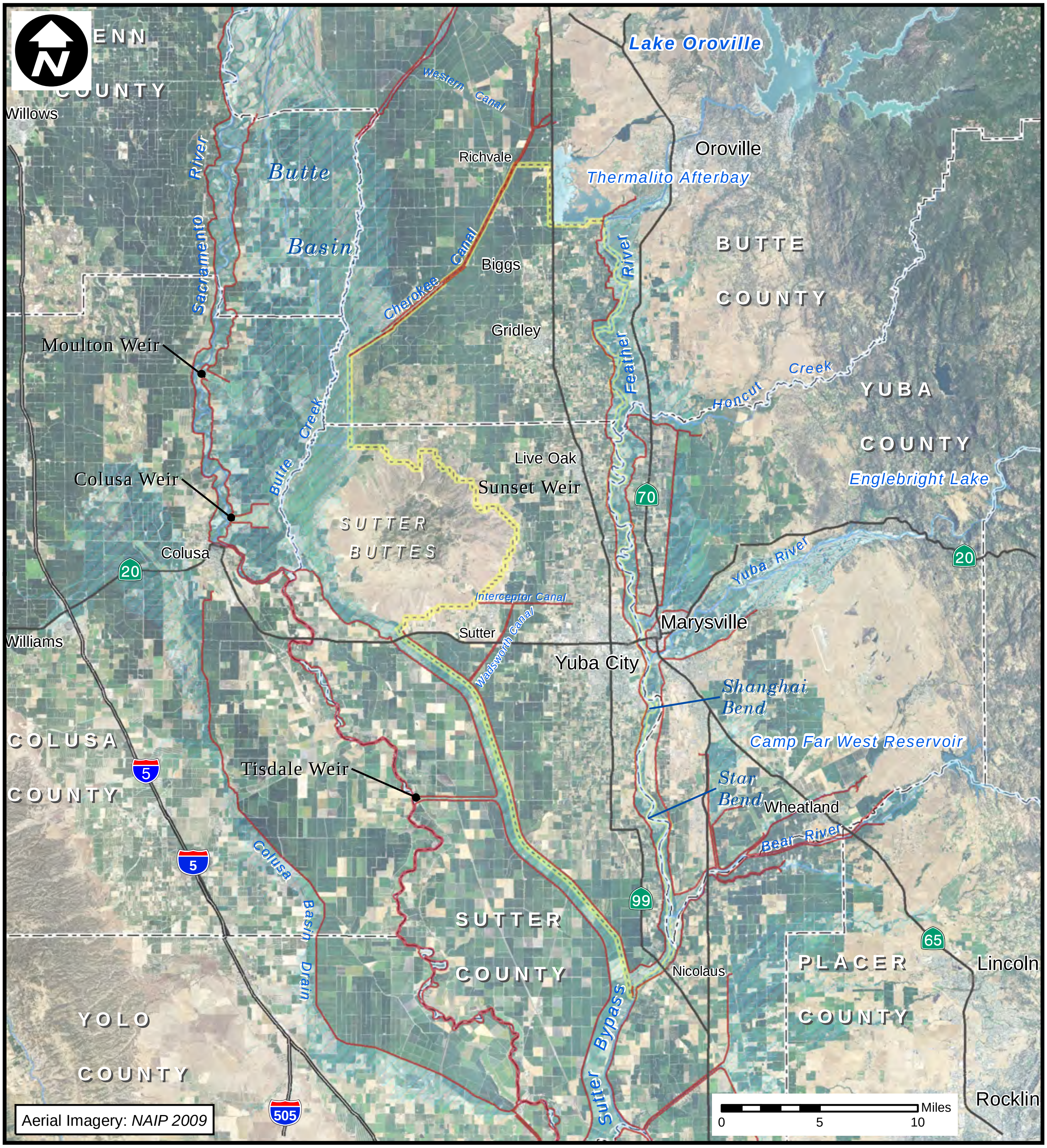
STUDY AREA TOPOGRAPHY

U.S. ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT

Prepared by Jim Mars

FEB 2013

PLATE 2



Legend

Study Area Extent	Federal Levee
Designated Floodways	County Boundary
Lake or Reservoir	City or Town
River or Stream	

SUTTER BASIN PILOT FEASIBILITY STUDY
SUTTER BASIN, CALIFORNIA

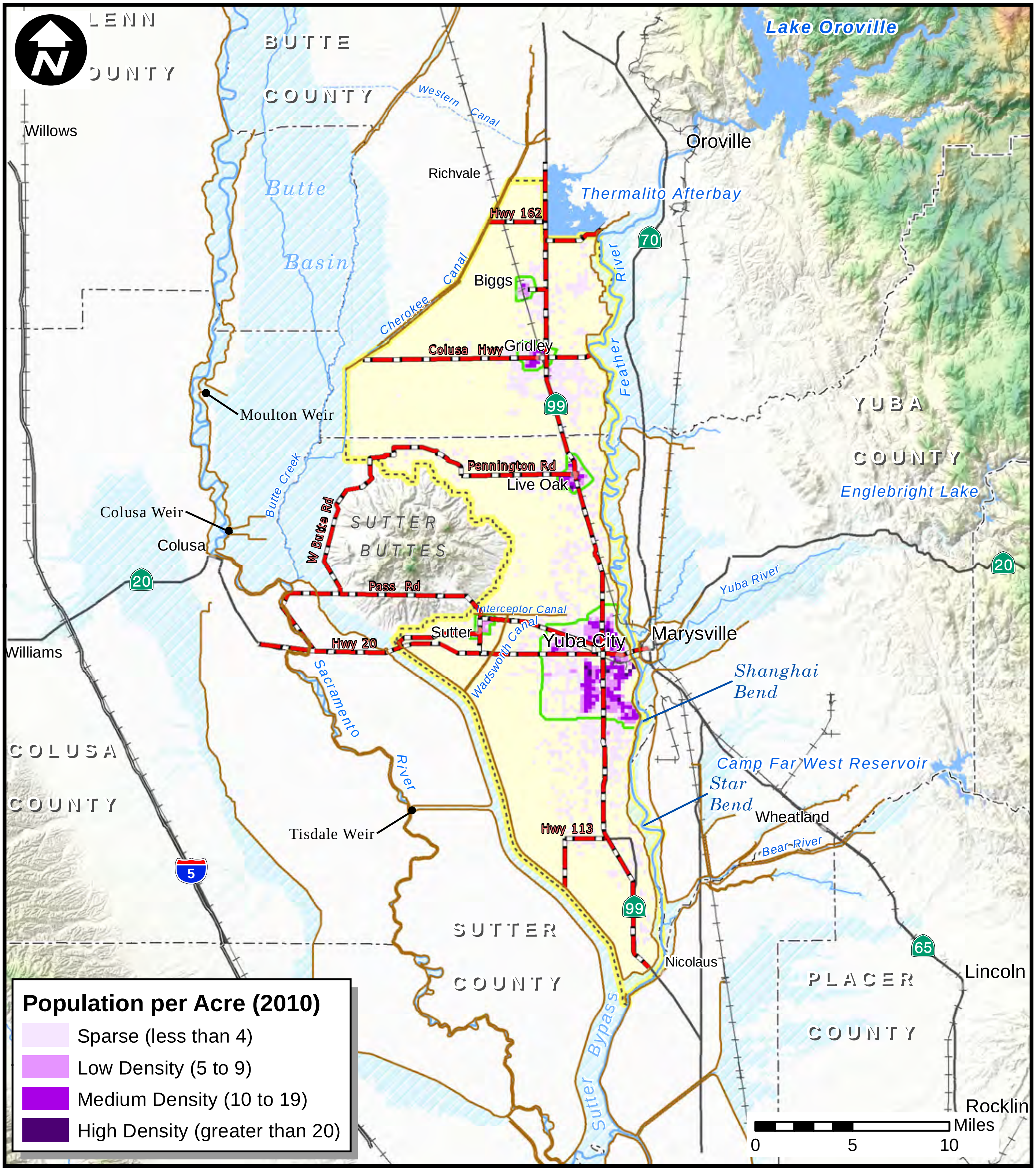
STUDY AREA
AERIAL IMAGERY

U.S. ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT

Prepared by Jim Mars

FEB 2013

PLATE 3



Legend

- Federal Levee
- River or Stream
- Lake or Reservoir
- Designated Floodways
- Study Area Extent
- Evacuation Routes
- Highway
- Railroad
- County Boundary

SUTTER BASIN PILOT FEASIBILITY STUDY
SUTTER BASIN, CALIFORNIA

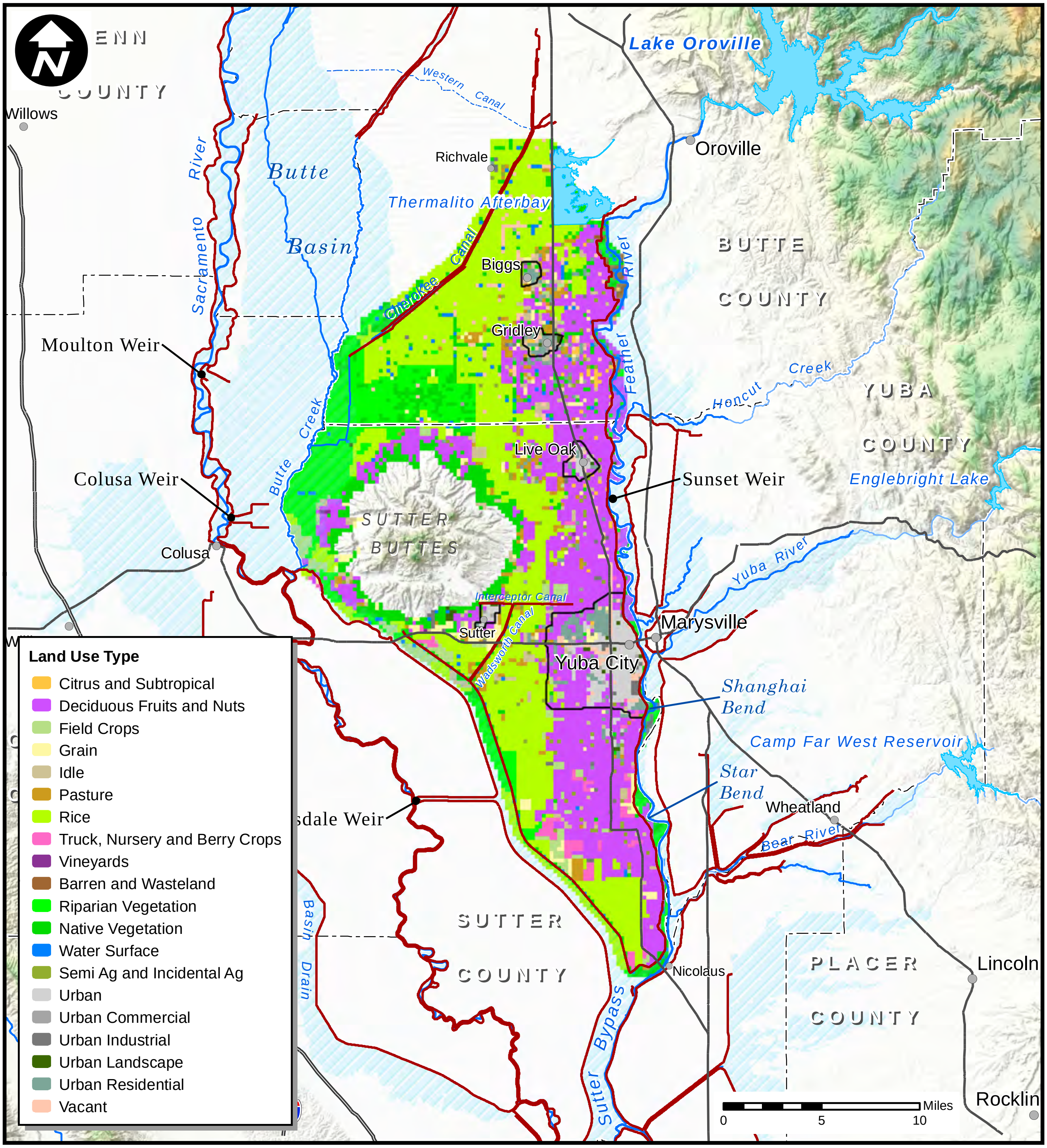
POPULATION DENSITY

U.S. ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT

Prepared by Jim Mars

FEB 2013

PLATE 4



Legend

Designated Floodways	Federal Levee
Lake or Reservoir	County Boundary
River or Stream	City or Town

SUTTER BASIN PILOT FEASIBILITY STUDY
SUTTER BASIN, CALIFORNIA

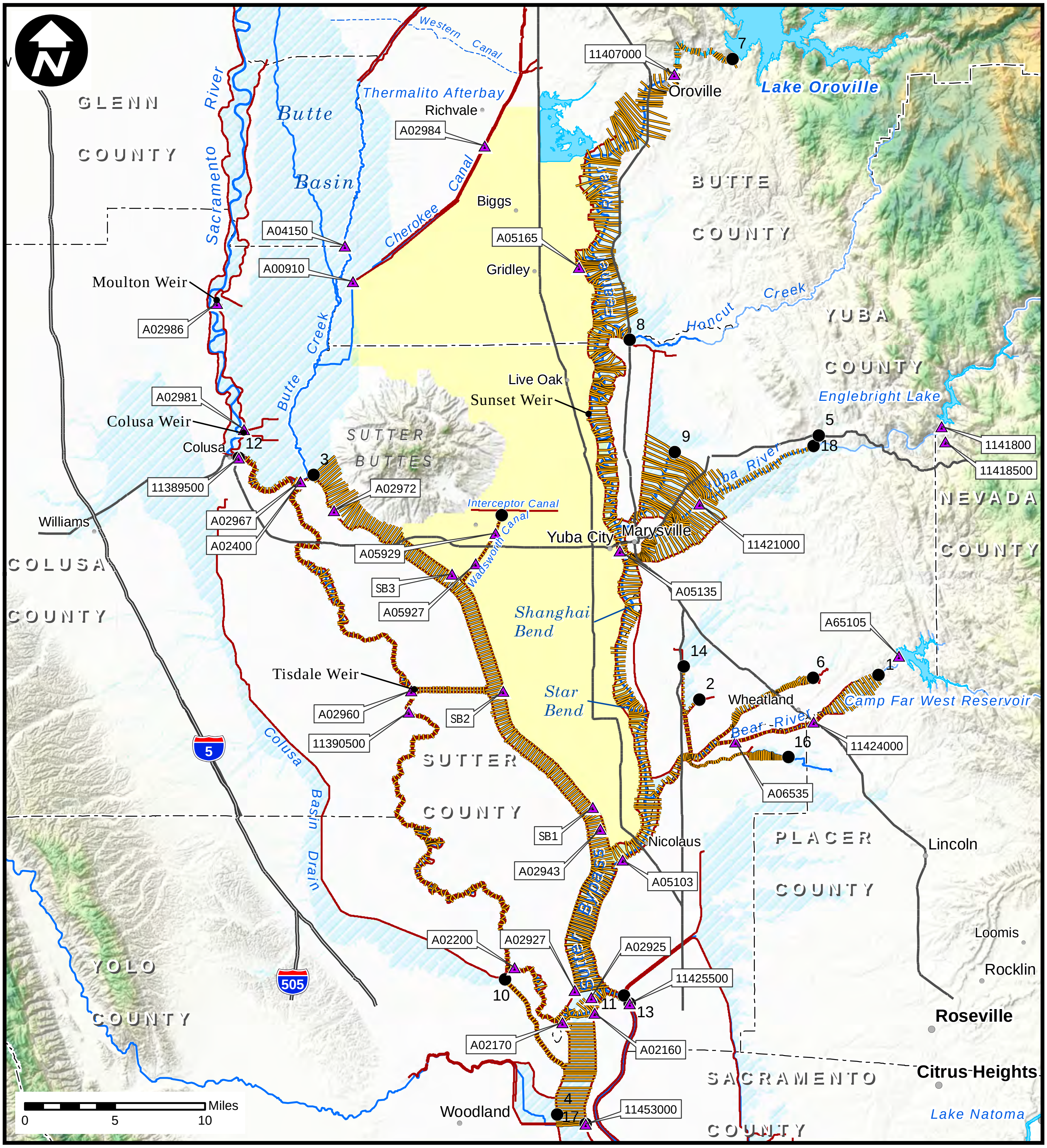
LAND USE

U.S. ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT

Prepared by Jim Mars

FEB 2013

PLATE 5



Legend

- Stream Gage
- Model Boundaries
- Model Cross Sectios
- Federal Levee
- Study Area Extent
- Designated Floodways

NOTE: See Table 1 and 2 for Model Boundary Name

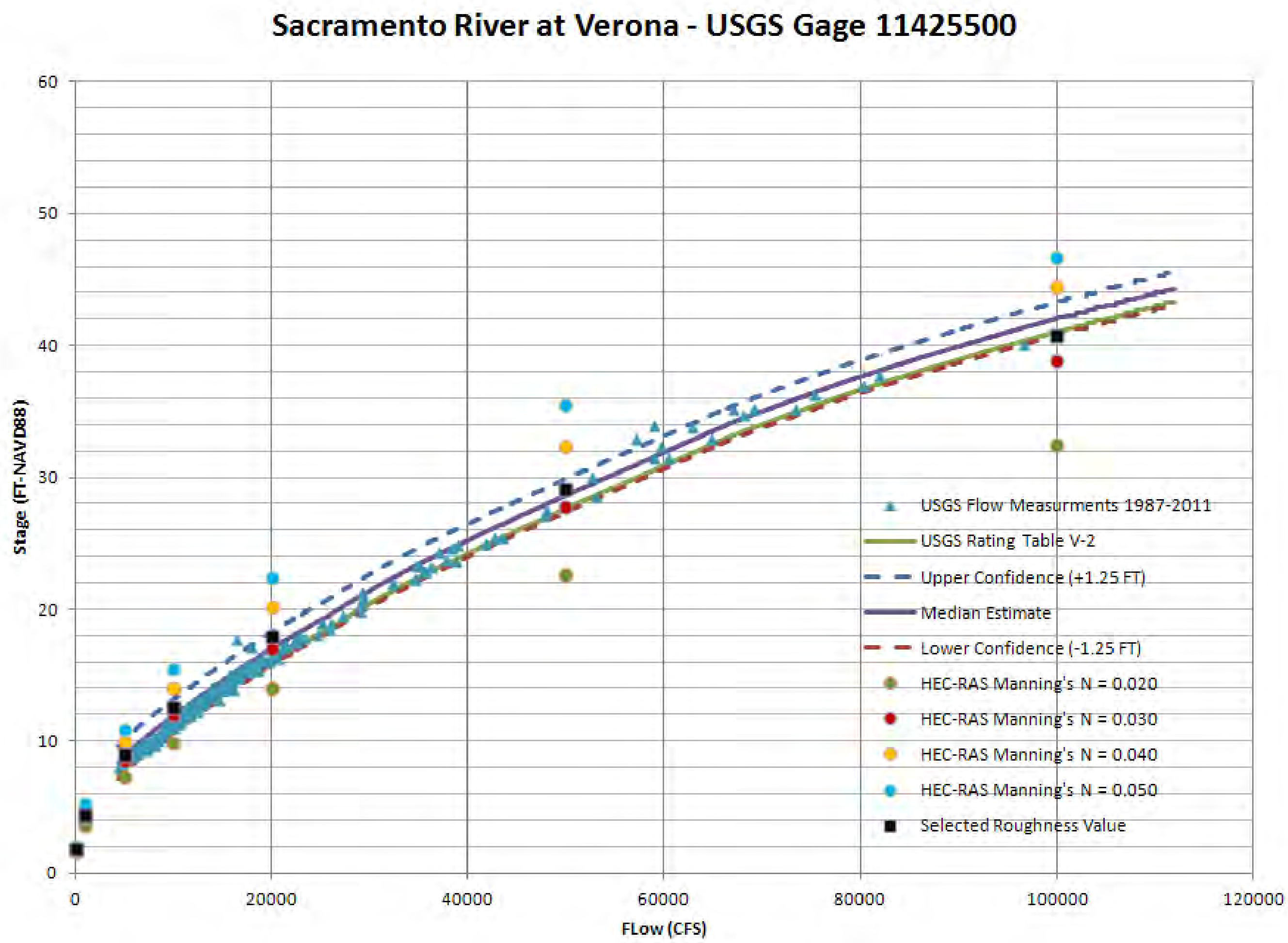
SUTTER BASIN PILOT FEASIBILITY STUDY
SUTTER BASIN, CALIFORNIA

HEC-RAS HYDRAULIC MODEL BOUNDARY CONDITIONS AND STREAM GAGES

U.S. ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT

Prepared by Jim Mars

FEB 2013

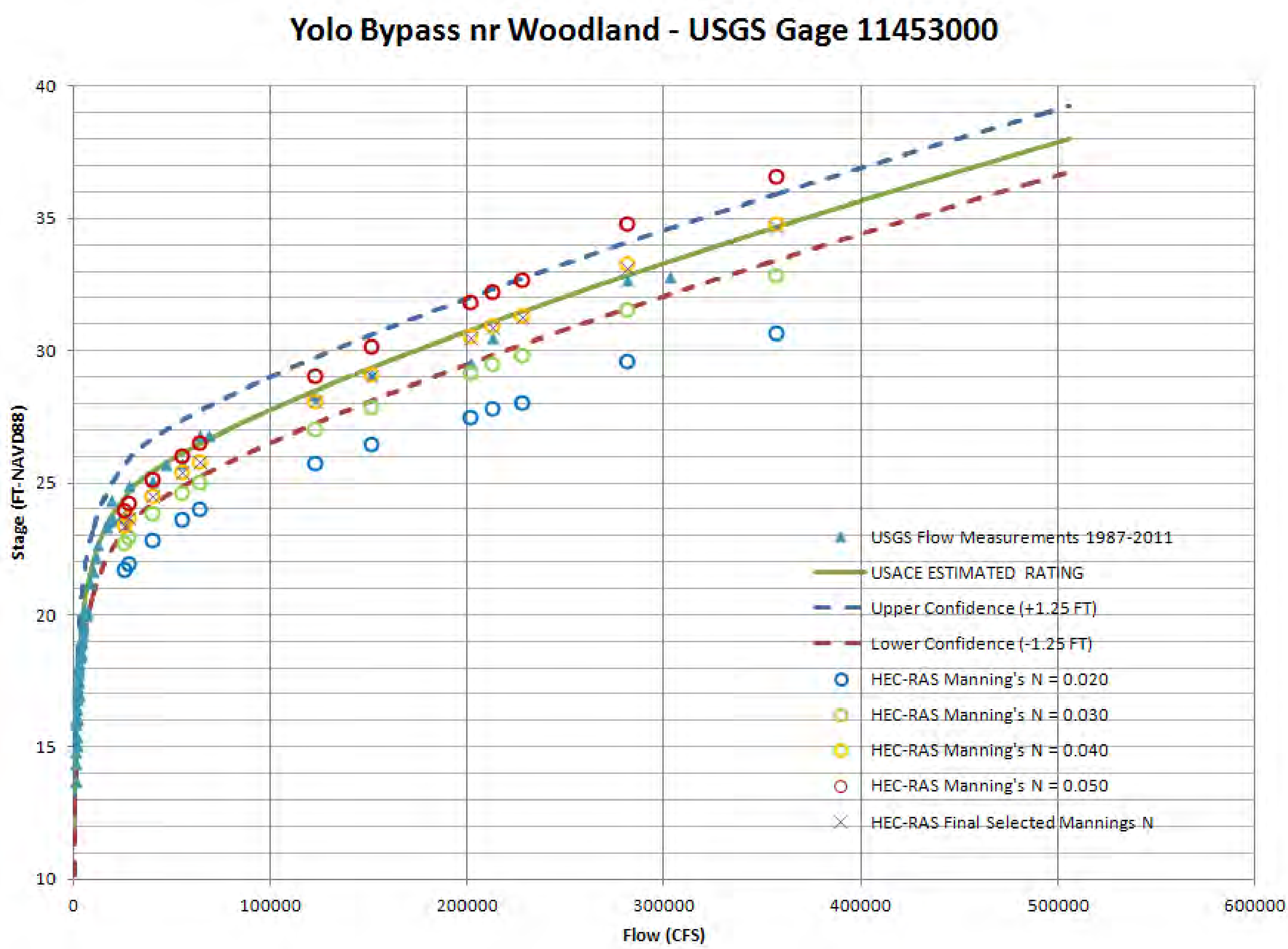


Source:

SUTTER BASIN PILOT FEASBILITY STUDY
SUTTER BASIN, CALIFORNIA

STAGE-DISCHARGE CURVE
SACRAMENTO RIVER AT VERONA
WITHOUT PROJECT CONDITIONS

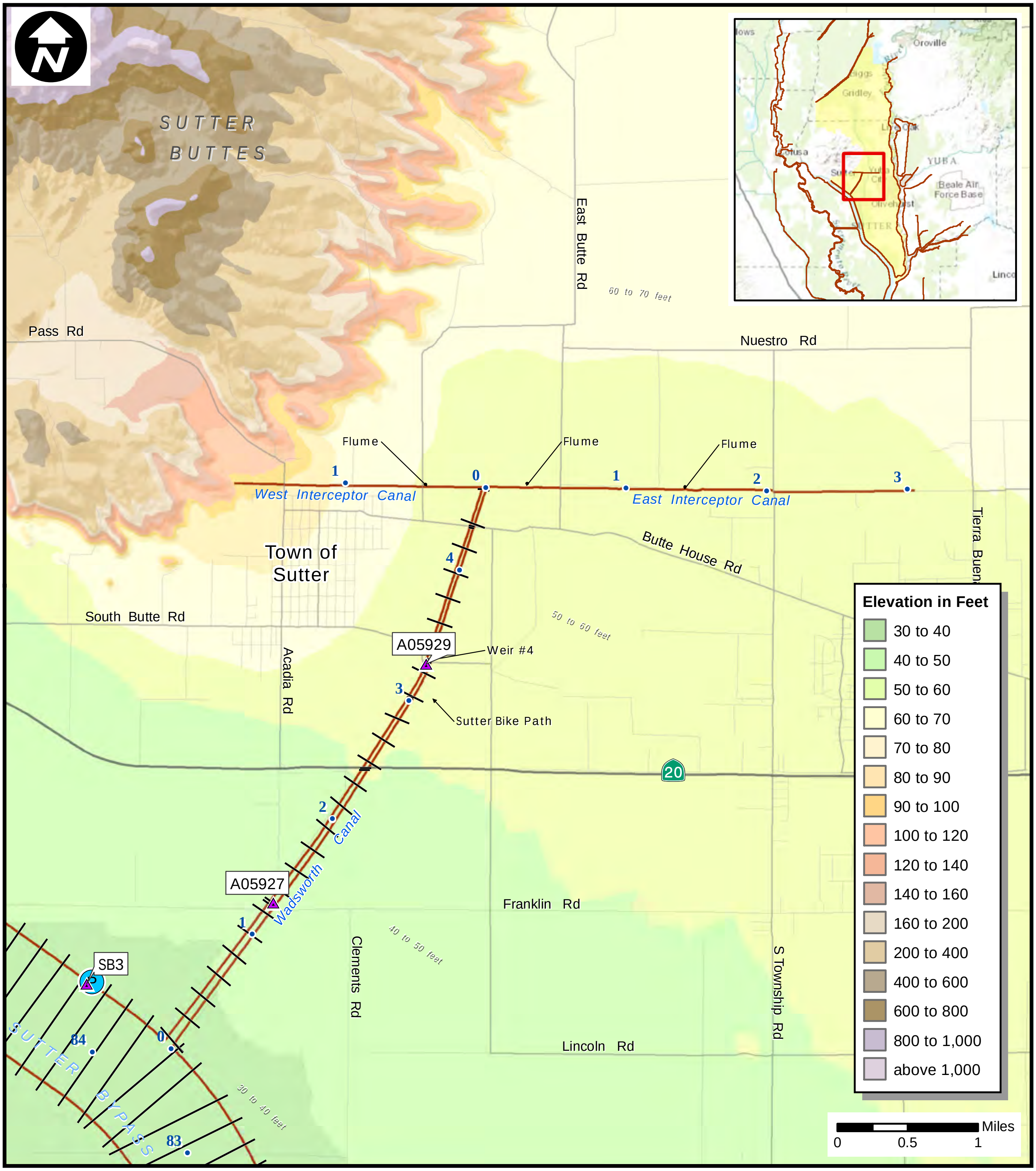
U.S ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT



SUTTER BASIN PILOT FEASBILITY STUDY
SUTTER BASIN, CALIFORNIA

STAGE-DISCHARGE CURVE
YOLO BYPASS AT WOODLAND
WITHOUT PROJECT CONDTIONS

U.S ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT



Legend

Model Cross Sectios

Federal Levee

Pump Station

Comp Study River Mile

Note: Topography data is from the USGS DEM and is in NAVD88

SUTTER BASIN PILOT FEASIBILITY STUDY
SUTTER BASIN, CALIFORNIA

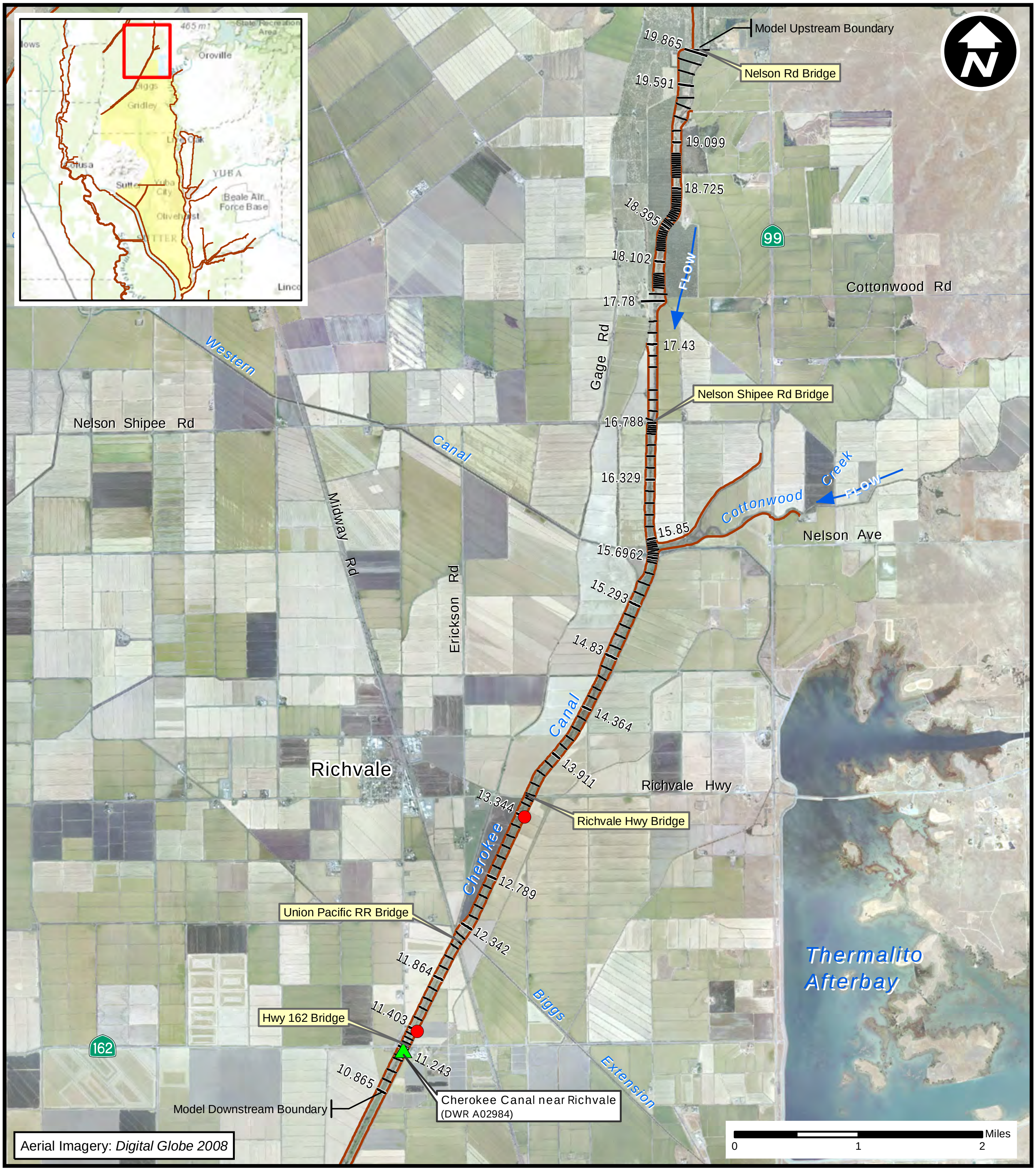
WADSWORTH AND INTERCEPTOR CANALS TOPOGRAPHY

U.S. ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT

Prepared by Jim Mars

FEB 2013

PLATE 9



Legend

Stream Gage

Breach Simulation Point

Model Cross Sections

Federal Levee

SUTTER BASIN PILOT FEASIBILITY STUDY
SUTTER BASIN, CALIFORNIA

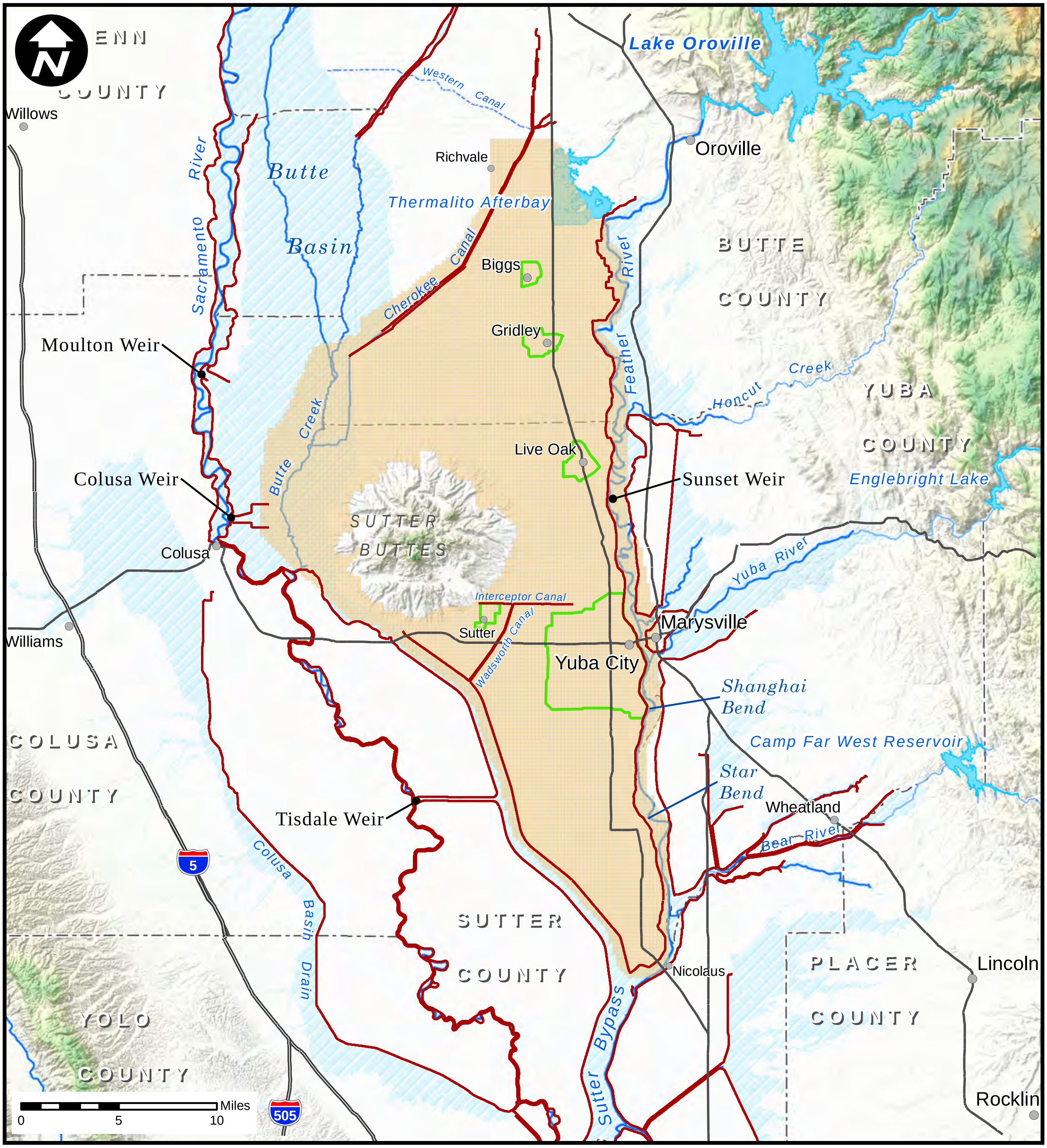
CHEROKEE CANAL HYDRAULIC MODEL

U.S. ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT

Prepared by Jim Mars

MAR 2013

PLATE 10



Legend

- FLO2D Grid - 1000 ft
- Designated Floodways
- Lake or Reservoir
- Economic Evaluation Area
- River or Stream
- Federal Levee
- County Boundary
- City or Town

SUTTER BASIN PILOT FEASIBILITY STUDY
SUTTER BASIN, CALIFORNIA

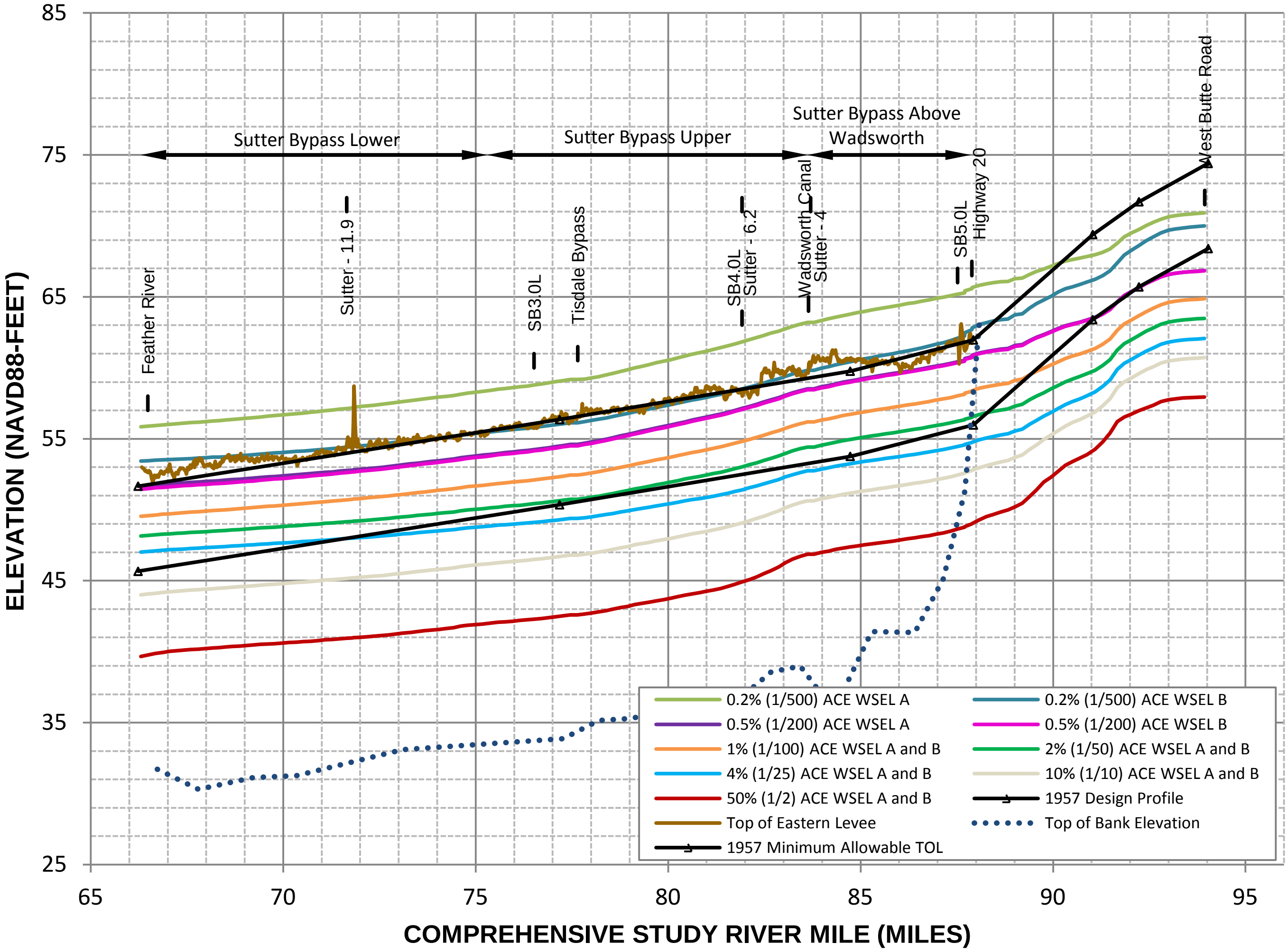
FLO2D MODEL GRID

U.S. ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT

Prepared by Jim Mars

FEB 2013

PLATE 11



Note:

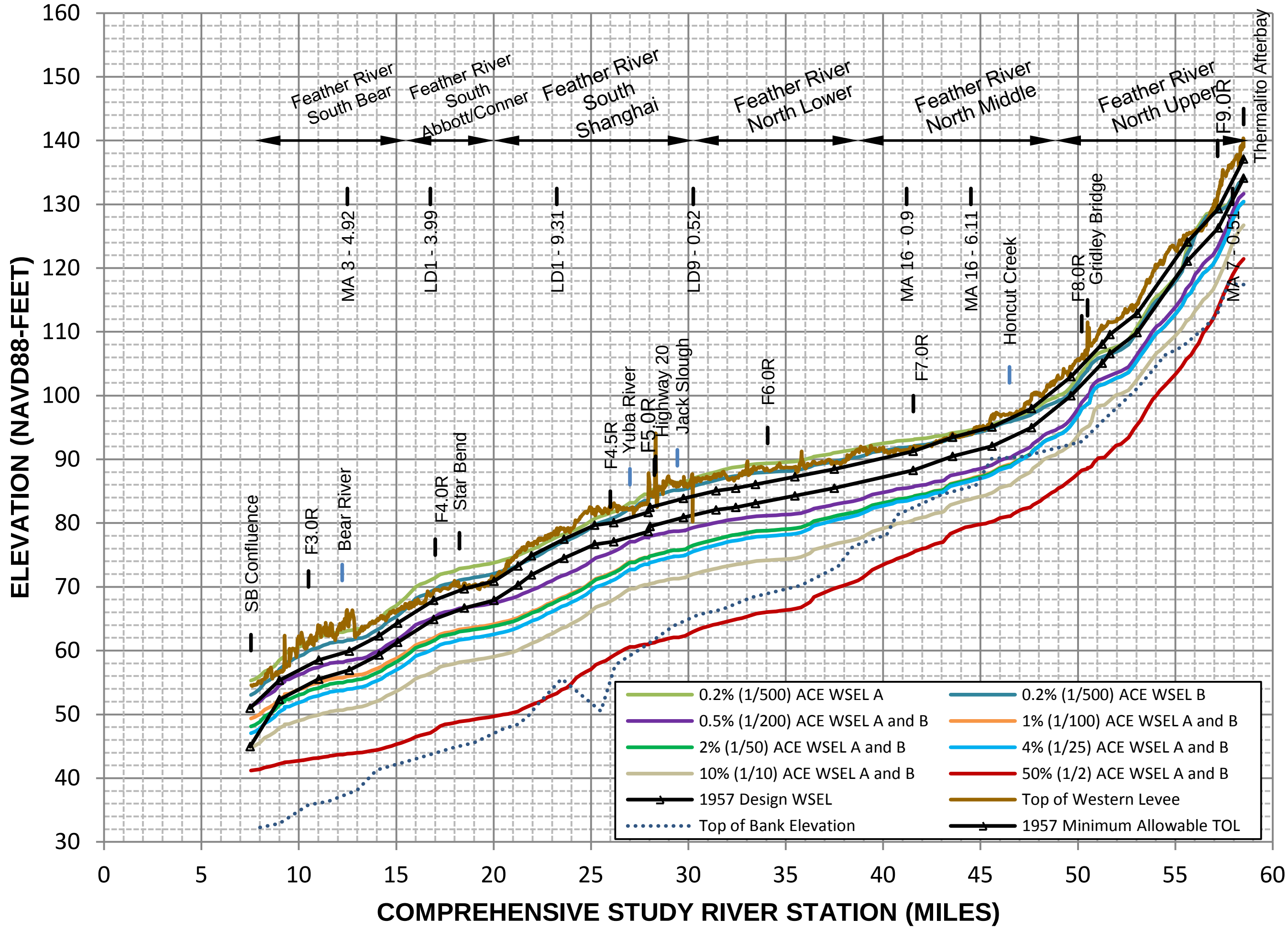
Water Surface Profile A assumes infinite levee height, no overtopping

Water Surface Profile B assumes overtopping only, no failure

WSEL = Water Surface Elevation

Source:

SUTTER BASIN PILOT FEASBILITY STUDY **SUTTER BASIN, CALIFORNIA**
SUTTER BYPASS **WATER SURFACE PROFILES**
U.S ARMY CORPS OF ENGINEERS **SACRAMENTO DISTRICT**



Note:

Water Surface Profile A assumes infinite levee height, no overtopping

Water Surface Profile B assumes overtopping only, no failure

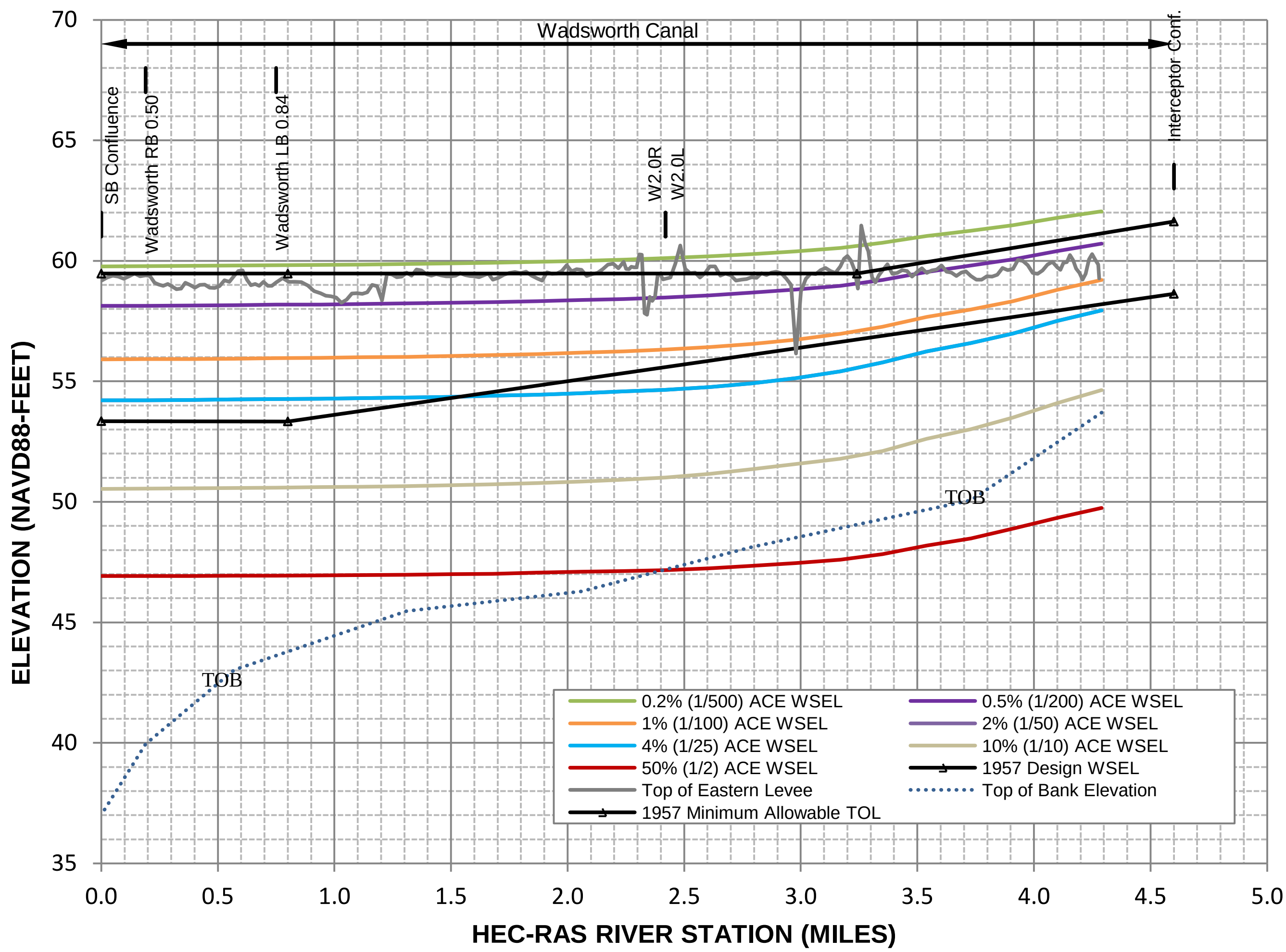
WSEL = Water Surface Elevation

Source:

SUTTER BASIN PILOT FEASBILITY STUDY
SUTTER BASIN, CALIFORNIA

FEATHER RIVER
WATER SURFACE PROFILES

U.S ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT



Note:

Water Surface Profile A assumes infinite levee height, no overtopping

Overtopping, no failure was not created for Wadsworth Canal

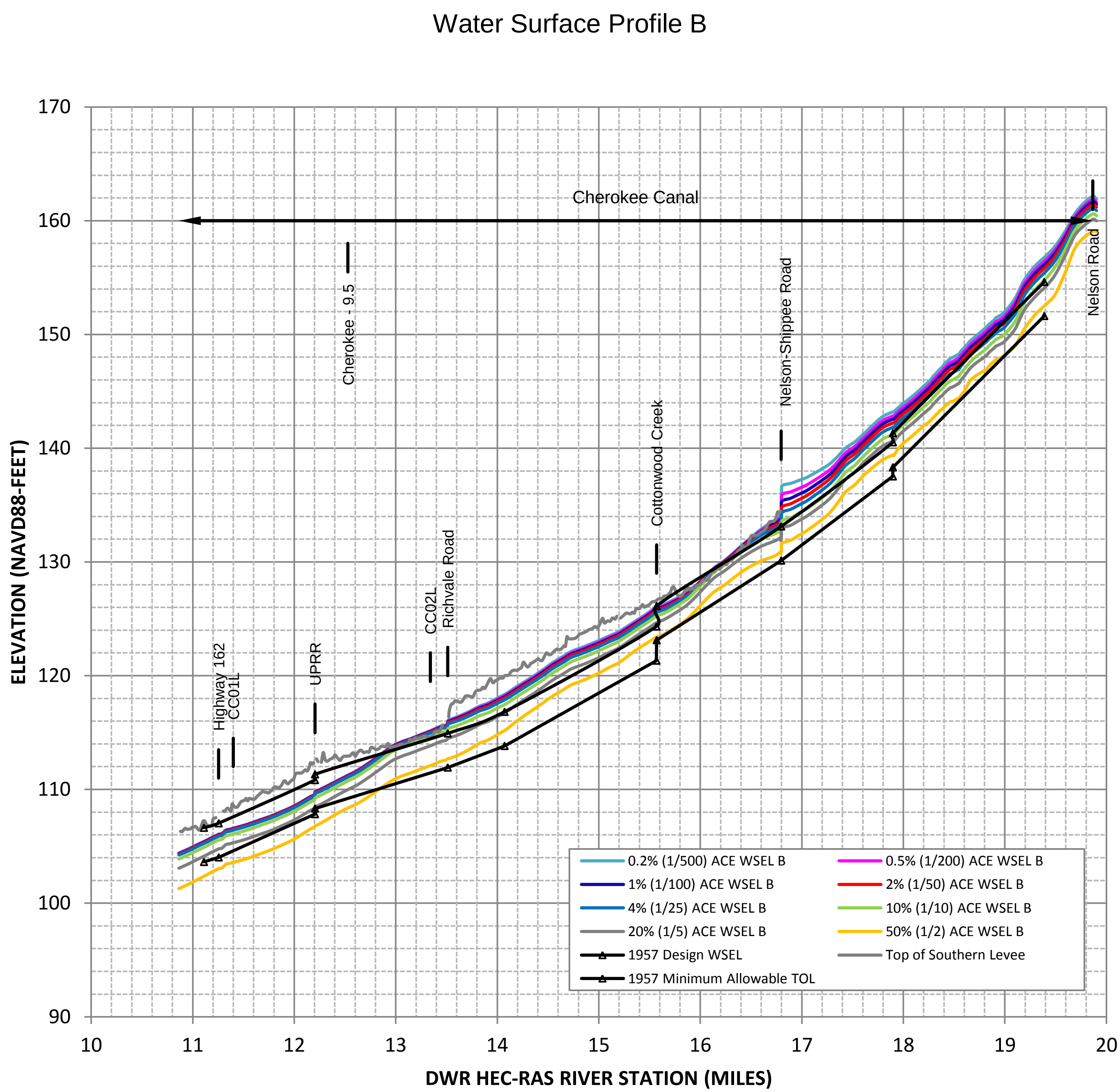
WSEL = Water Surface Elevation

Source:

SUTTER BASIN PILOT FEASBILITY STUDY
SUTTER BASIN, CALIFORNIA

WADSWORTH CANAL
WATER SURFACE PROFILES

U.S ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT



Notes:

Water Surface Profile B assumes overtopping only, no failure.

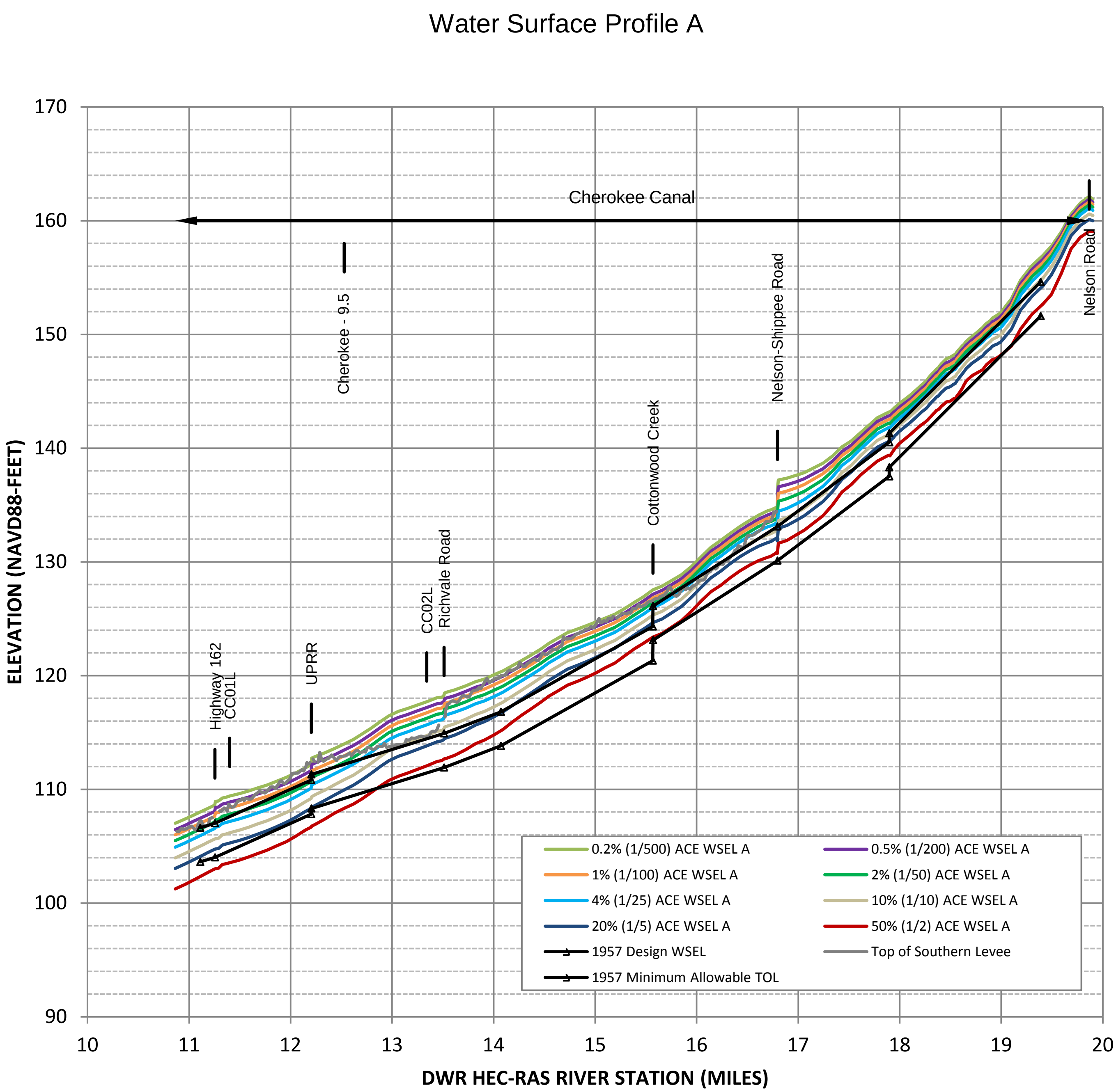
WSEL = Water Surface Elevation

Source:

SUTTER BASIN FEASBILITY STUDY
SUTTER BASIN, CALIFORNIA

CHEROKEE CANAL
WATER SURFACE PROFILES

U.S ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT



Notes:

Water Surface Profile A assumes infinite levee height, no overtopping.

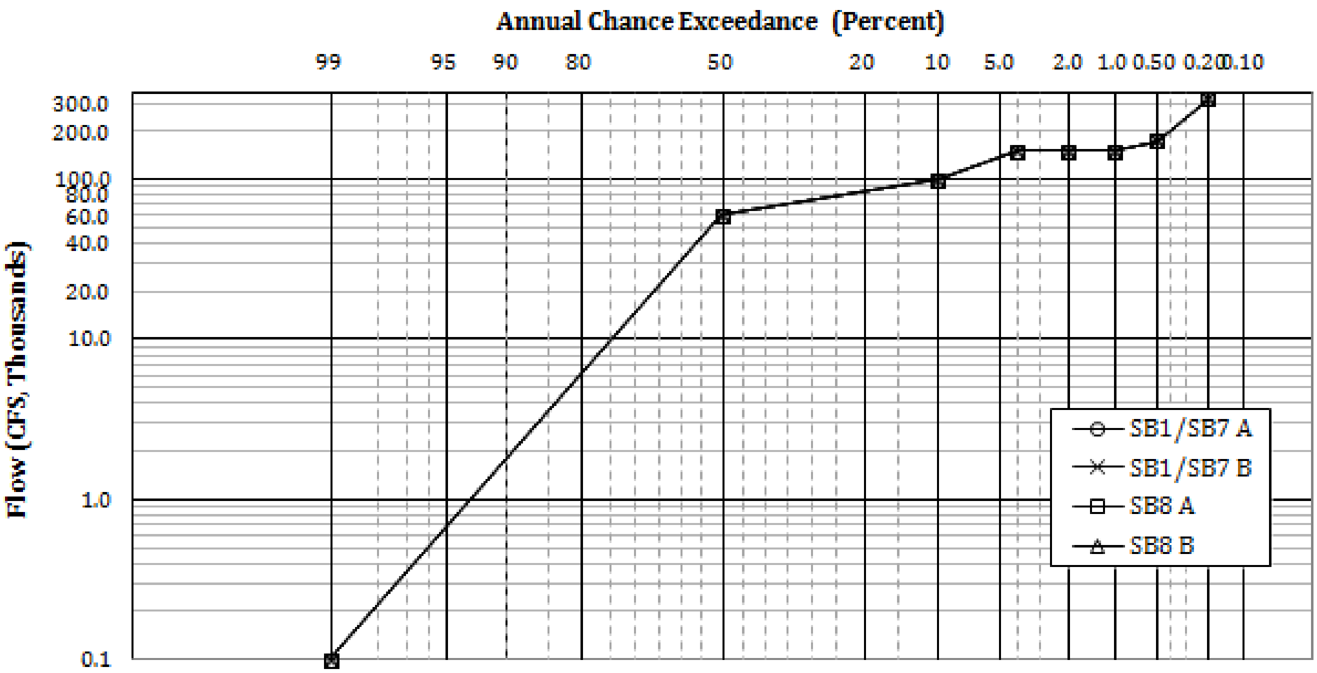
WSEL = Water Surface Elevation

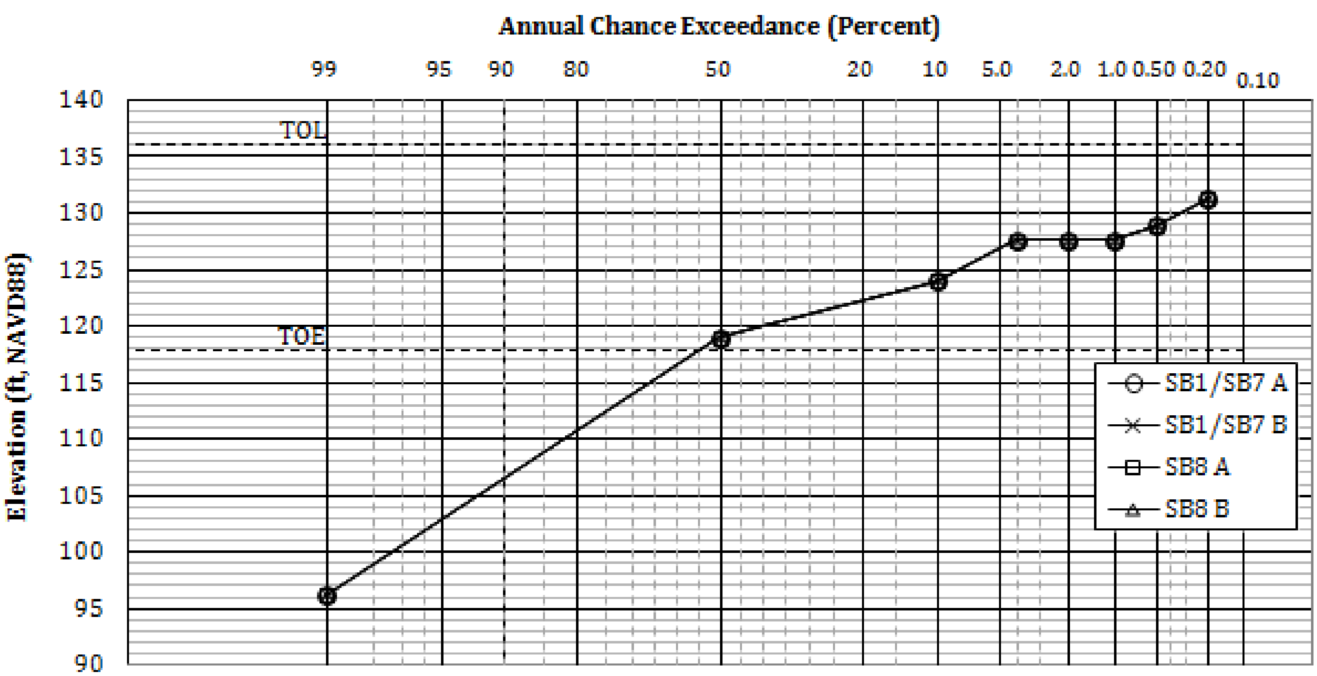
Source:

SUTTER BASIN FEASBILITY STUDY
SUTTER BASIN, CALIFORNIA

CHEROKEE CANAL WATER SURFACE PROFILES

U.S ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT





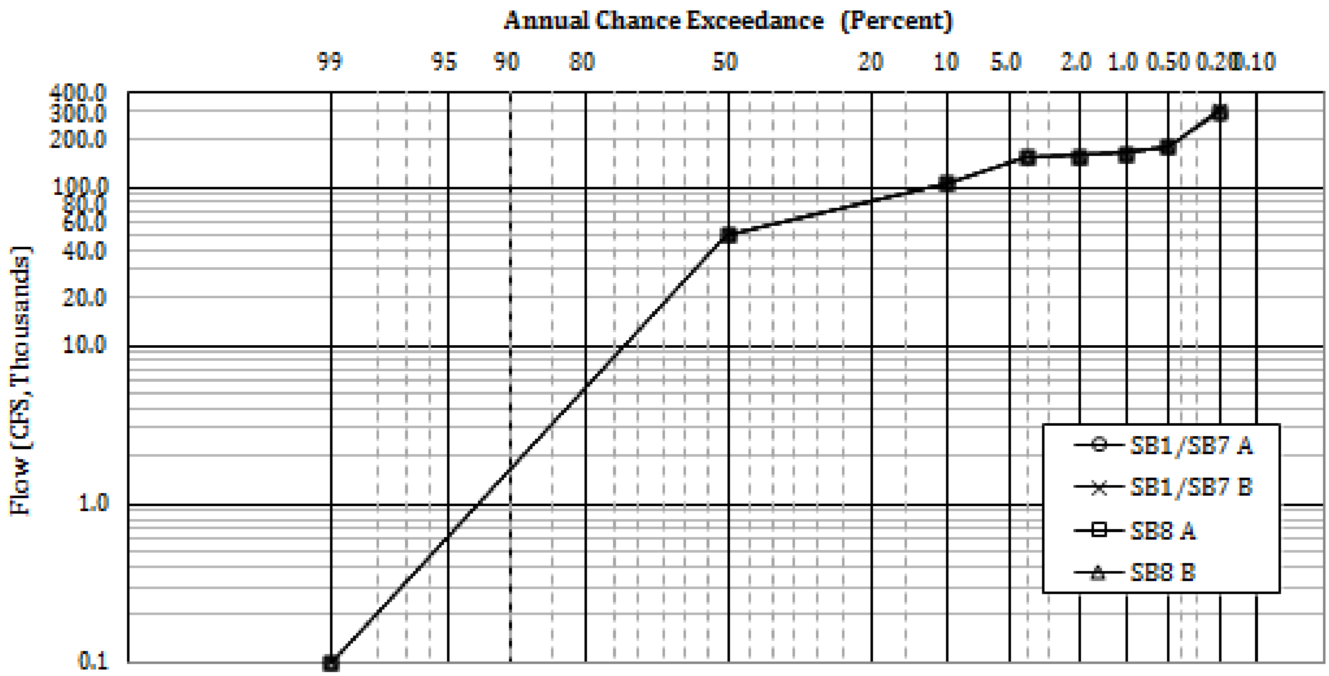
NOTES:
Feather River at Comp Study RM 57.95 refers to Geotechnical index location MA7 – 0.51
TOL = top of levee from 2008 NLDB
TOE = average elevation of bank line adjacent to levee
SB1 – Without Project Conditions
SB7 – Fix in Place Sunset Weir to Laurel Avenue
SB8 – Fix in Place Thermalito to Laurel Avenue
Scenario A – Assumes infinite levee height
Scenario B – Assumes levee overtopping with no failure

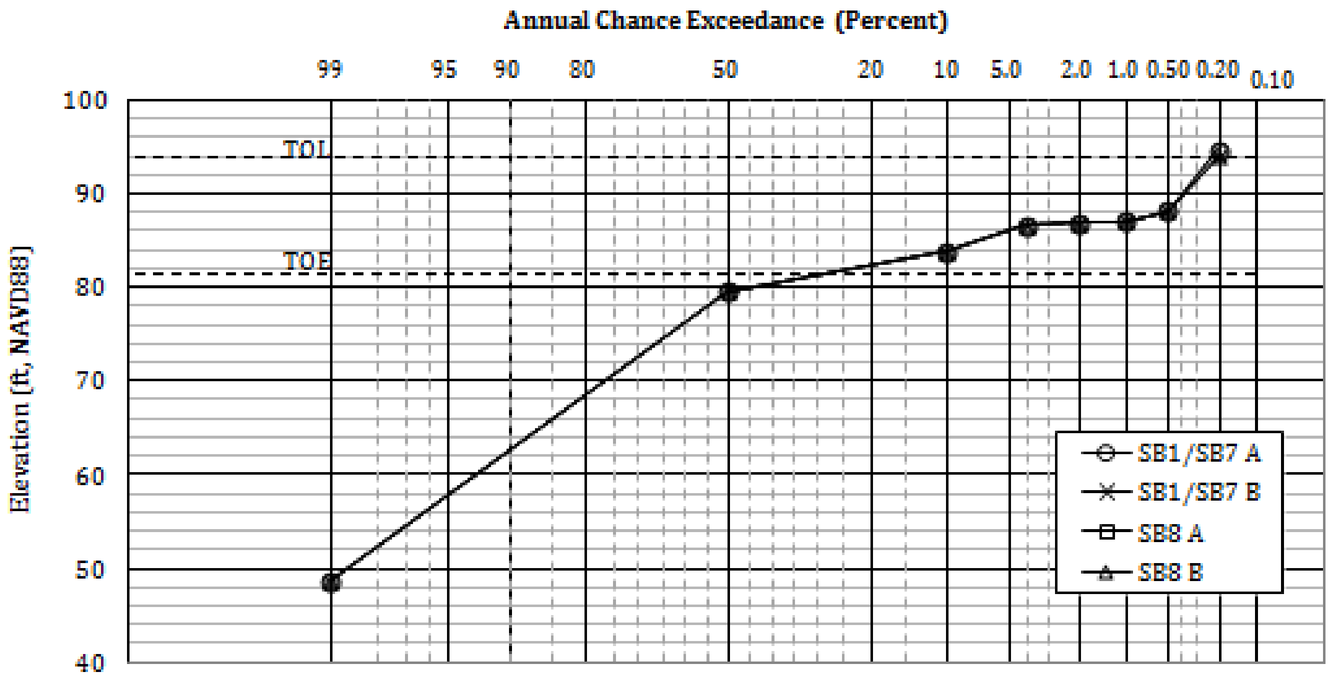
Source:

SUTTER BASIN PILOT FEASBILITY STUDY
SUTTER BASIN, CALIFORNIA

STAGE AND DISCHARGE
FREQUENCY CURVES
FEATHER RIVER AT RM 57.95

U.S ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT





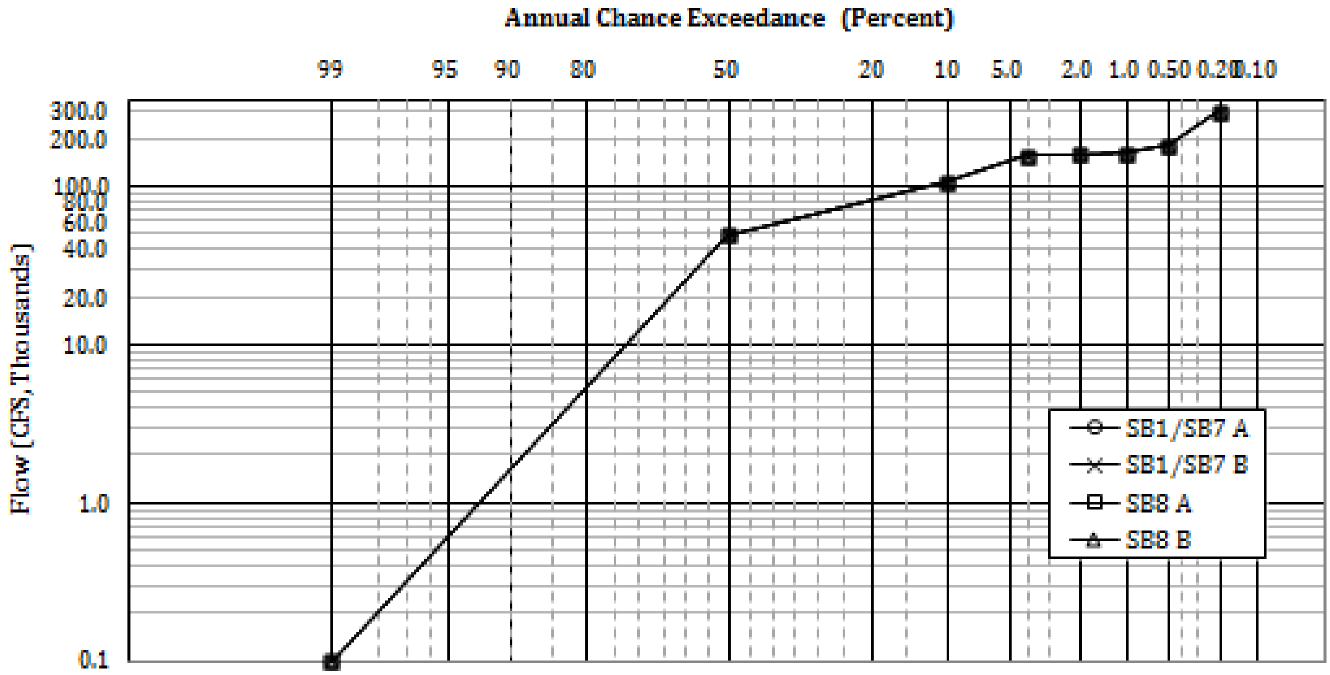
NOTES:
Feather River at Comp Study RM 44.5 refers to Geotechnical index location MA 16 – 2.9
TOL = top of levee from 2008 NLDB
TOE = average elevation of bank line adjacent to levee
SB1 – Without Project Conditions
SB7 – Fix in Place Sunset Weir to Laurel Avenue
SB8 – Fix in Place Thermalito to Laurel Avenue
Scenario A – Assumes infinite levee height
Scenario B – Assumes levee overtopping with no failure

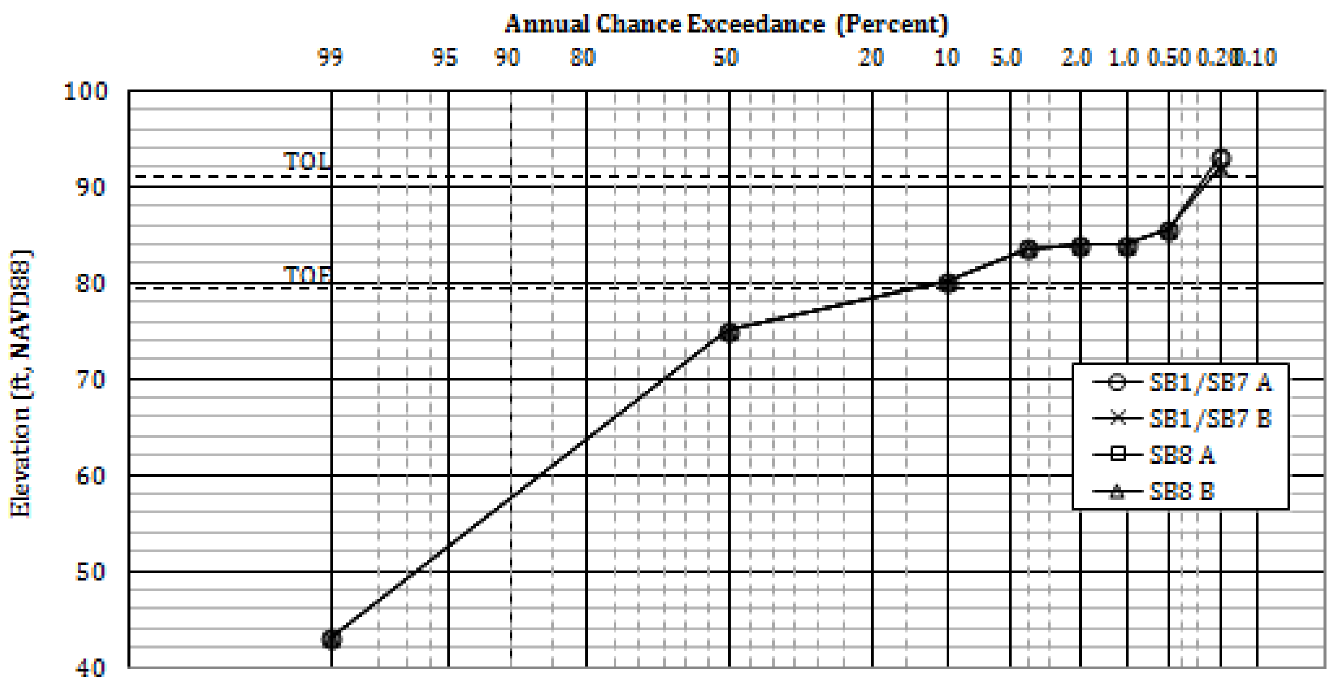
Source:

SUTTER BASIN PILOT FEASBILITY STUDY
SUTTER BASIN, CALIFORNIA

STAGE AND DISCHARGE
FREQUENCY CURVES
FEATHER RIVER AT RM 44.5

U.S ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT





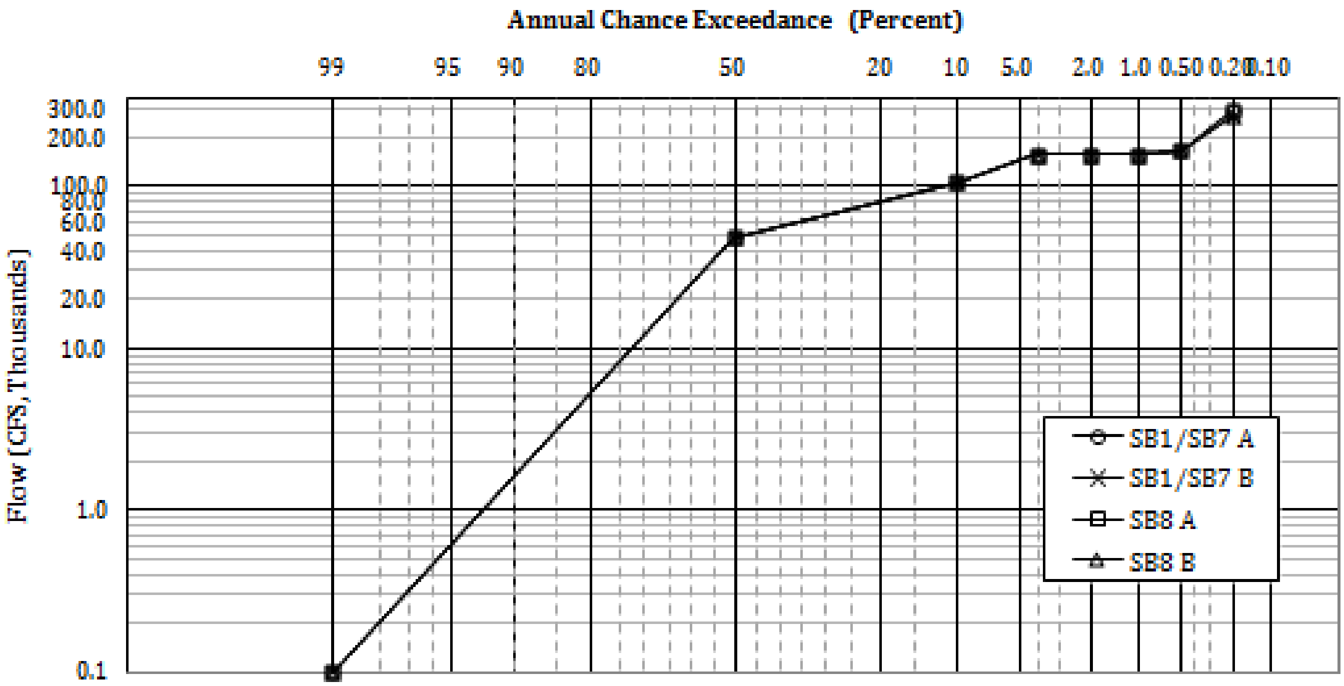
NOTES:
Feather River at Comp Study RM 41.2 refers to Geotechnical index location MA 16 – 0.9
TOL = top of levee from 2008 NLDB
TOE = average elevation of bank line adjacent to levee
SB1 – Without Project Conditions
SB7 – Fix in Place Sunset Weir to Laurel Avenue
SB8 – Fix in Place Thermalito to Laurel Avenue
Scenario A – Assumes infinite levee height
Scenario B – Assumes levee overtopping with no failure

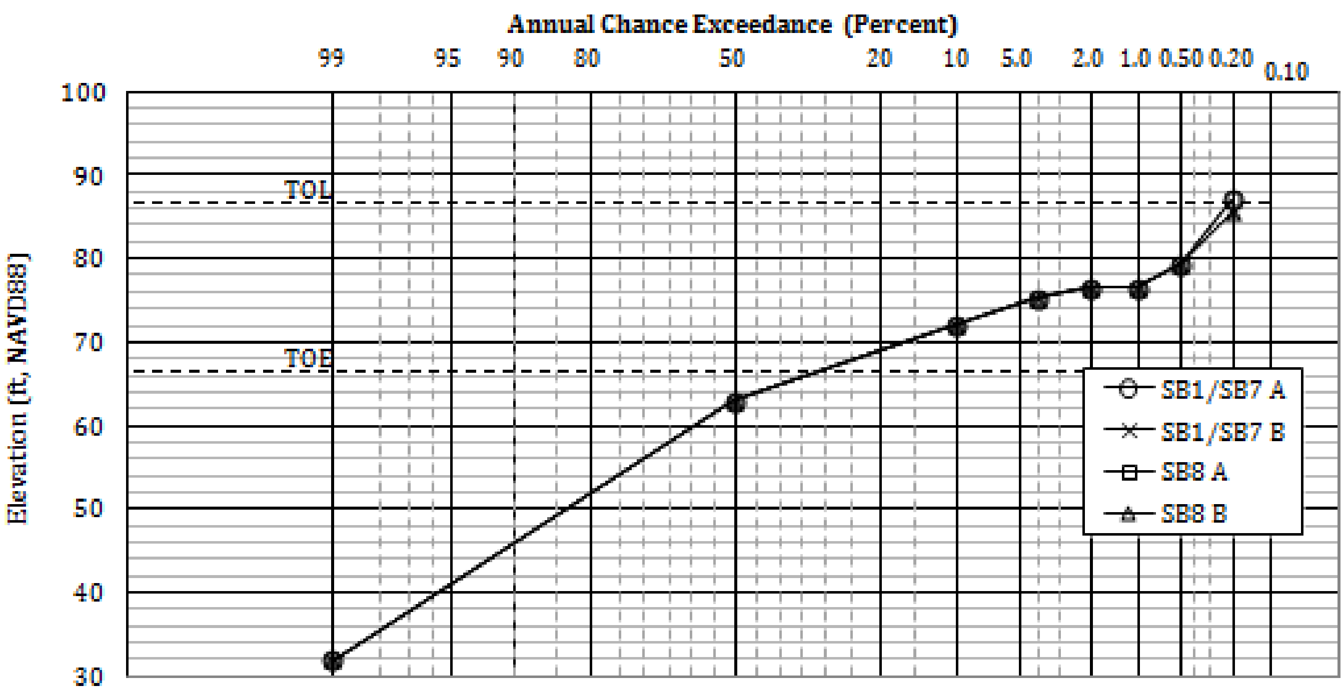
Source:

SUTTER BASIN PILOT FEASBILITY STUDY
SUTTER BASIN, CALIFORNIA

STAGE AND DISCHARGE
FREQUENCY CURVES
FEATHER RIVER AT RM 41.2

U.S ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT





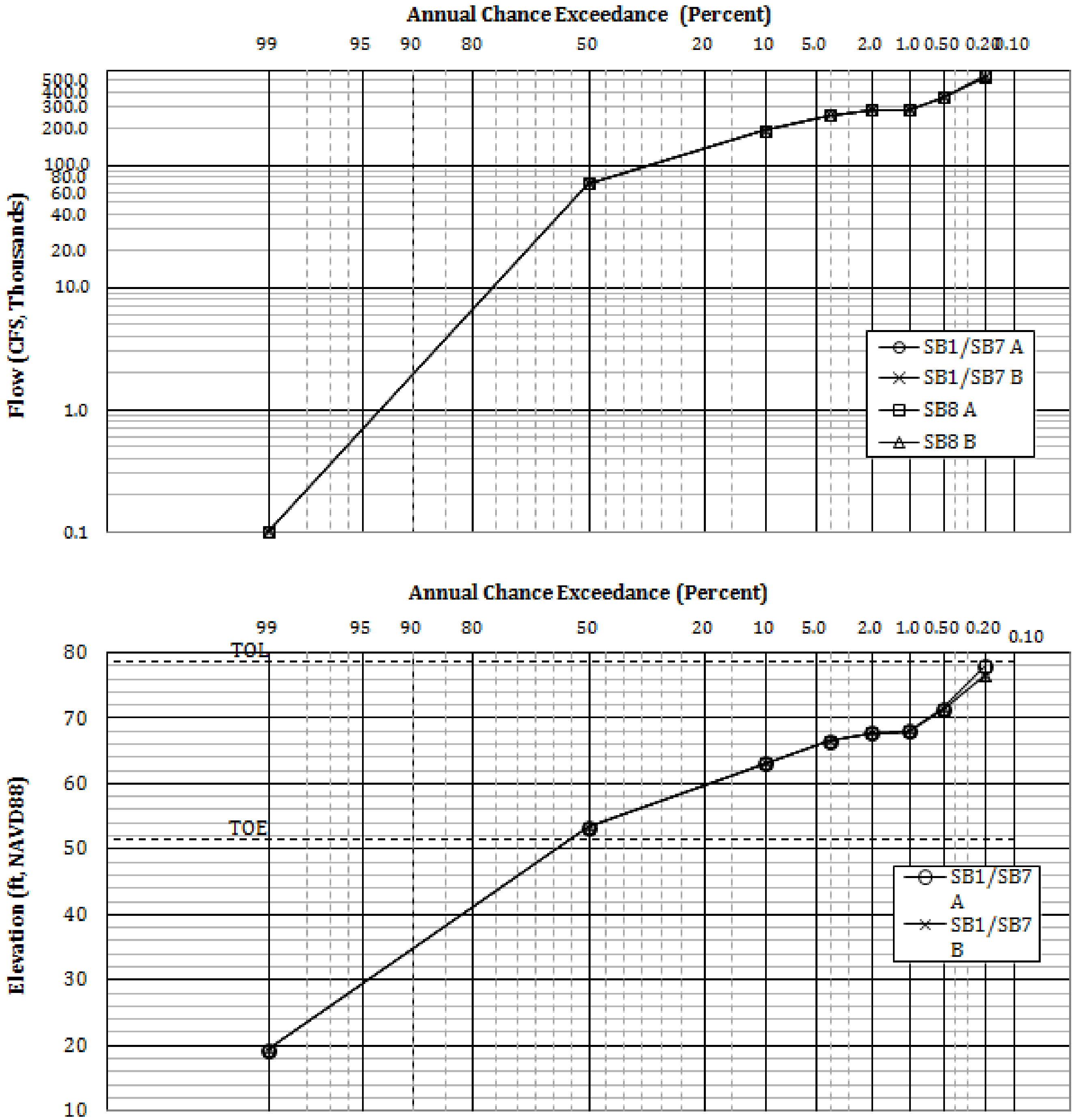
NOTES:
Feather River at Comp Study RM 30.25 refers to Geotechnical index location LD9 – 0.52
TOL = top of levee from 2008 NLDB
TOE = average elevation of bank line adjacent to levee
SB1 – Without Project Conditions
SB7 – Fix in Place Sunset Weir to Laurel Avenue
SB8 – Fix in Place Thermalito to Laurel Avenue
Scenario A – Assumes infinite levee height
Scenario B – Assumes levee overtopping with no failure

Sou

SUTTER BASIN PILOT FEASBILITY STUDY
SUTTER BASIN, CALIFORNIA

STAGE AND DISCHARGE
FREQUENCY CURVES
FEATHER RIVER AT RM 30.25

U.S ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT



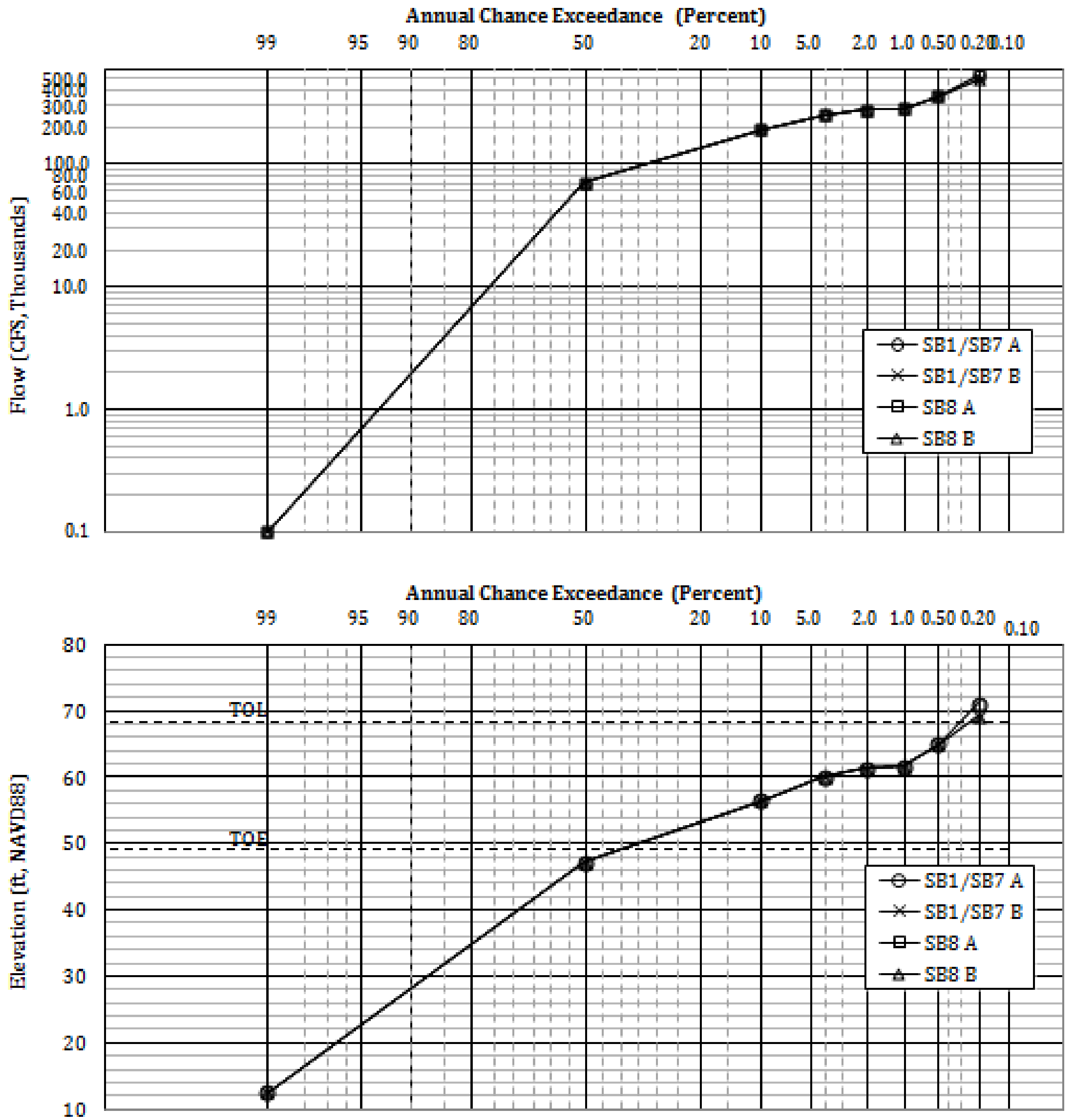
NOTES:
Feather River at Comp Study RM 23.25 refers to Geotechnical index location LD1 – 9.31
TOL = top of levee from 2008 NLDB
TOE = average elevation of bank line adjacent to levee
SB1 – Without Project Conditions
SB7 – Fix in Place Sunset Weir to Laurel Avenue
SB8 – Fix in Place Thermalito to Laurel Avenue
Scenario A – Assumes infinite levee height
Scenario B – Assumes levee overtopping with no failure

Source:

SUTTER BASIN PILOT FEASBILITY STUDY
SUTTER BASIN, CALIFORNIA

STAGE AND DISCHARGE FREQUENCY CURVES FEATHER RIVER AT RM 23.25

U.S ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT



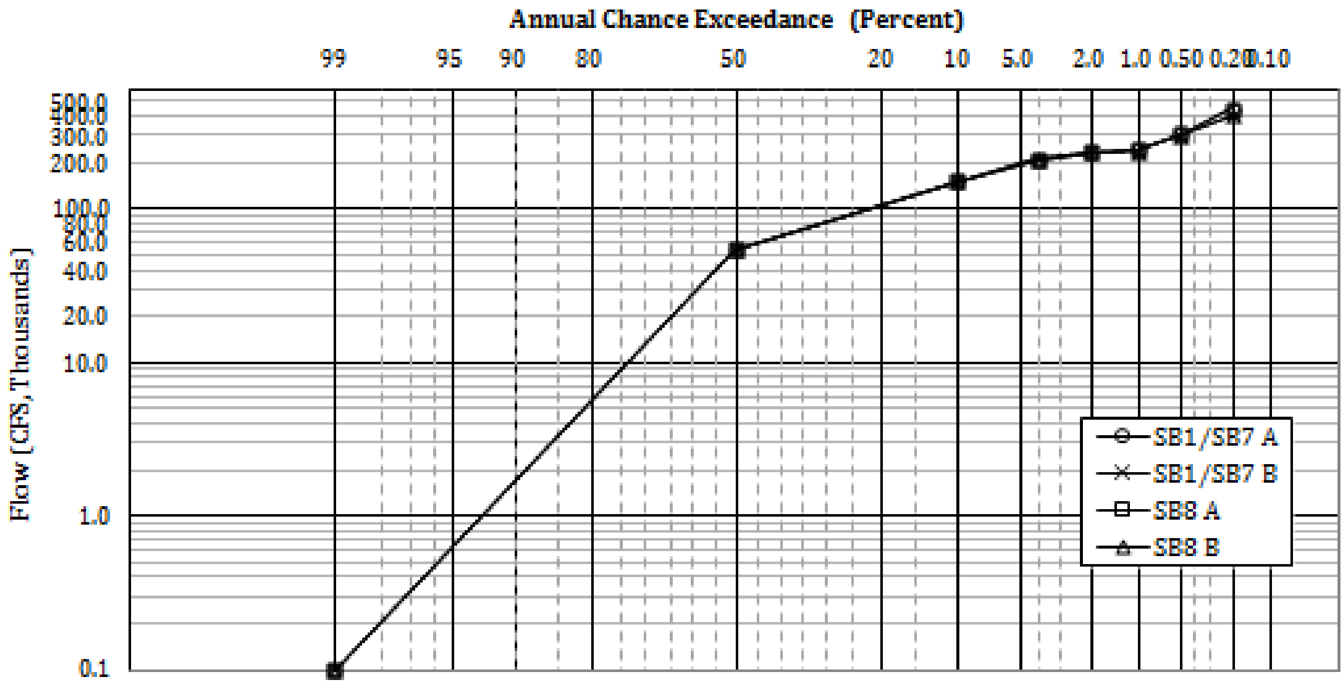
NOTES:
Feather River at Comp Study RM 16.75 refers to Geotechnical index location LD1 – 3.99
TOL = top of levee from 2008 NLDB
TOE = average elevation of bank line adjacent to levee
SB1 – Without Project Conditions
SB7 – Fix in Place Sunset Weir to Laurel Avenue
SB8 – Fix in Place Thermalito to Laurel Avenue
Scenario A – Assumes infinite levee height
Scenario B – Assumes levee overtopping with no failure

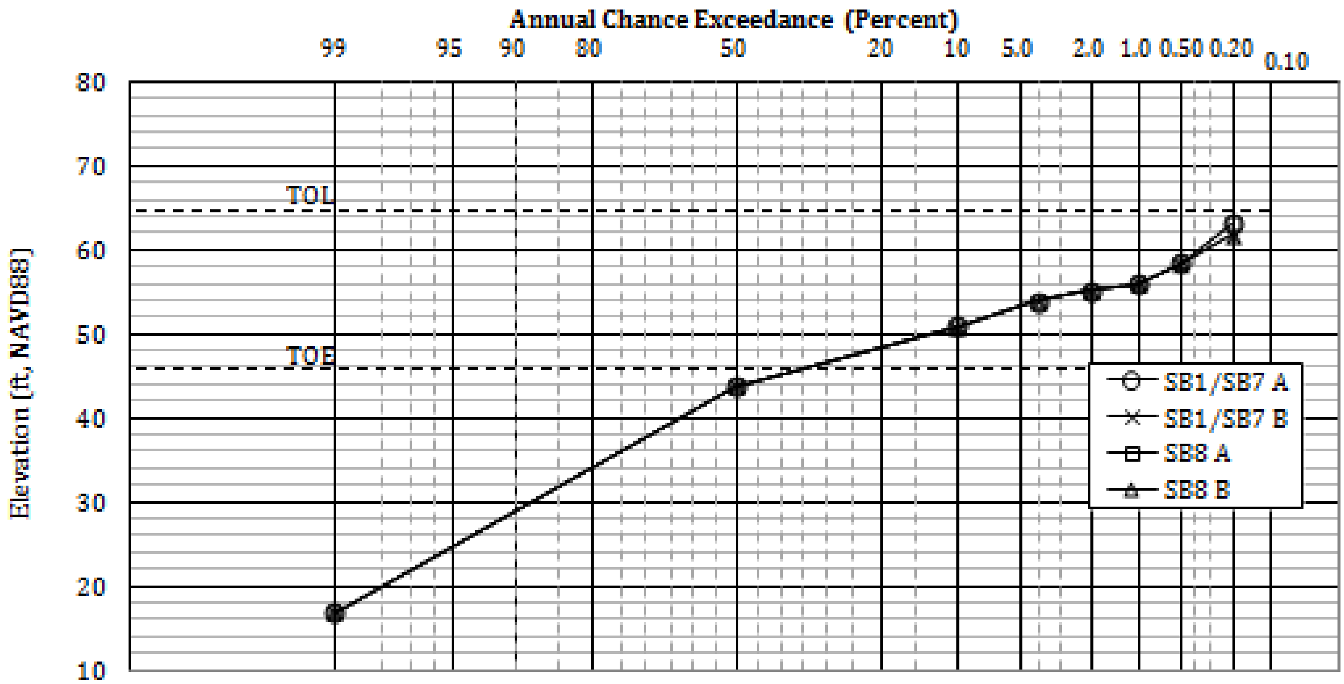
Source:

SUTTER BASIN PILOT FEASBILITY STUDY
SUTTER BASIN, CALIFORNIA

STAGE AND DISCHARGE
FREQUENCY CURVES
FEATHER RIVER AT RM 16.75

U.S ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT





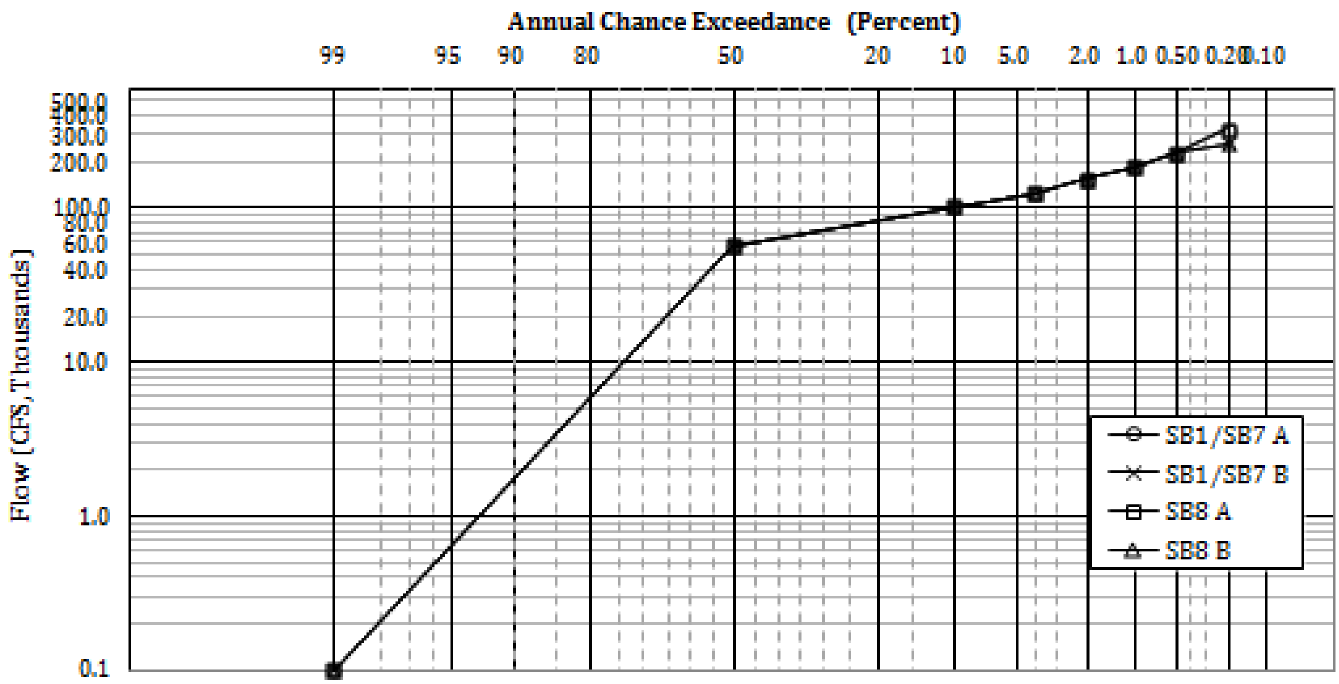
NOTES:
Feather River at Comp Study RM 12.5 refers to Geotechnical index location MA3 – 4.92
TOL = top of levee from 2008 NLDB
TOE = average elevation of bank line adjacent to levee
SB1 – Without Project Conditions
SB7 – Fix in Place Sunset Weir to Laurel Avenue
SB8 – Fix in Place Thermalito to Laurel Avenue
Scenario A – Assumes infinite levee height
Scenario B – Assumes levee overtopping with no failure

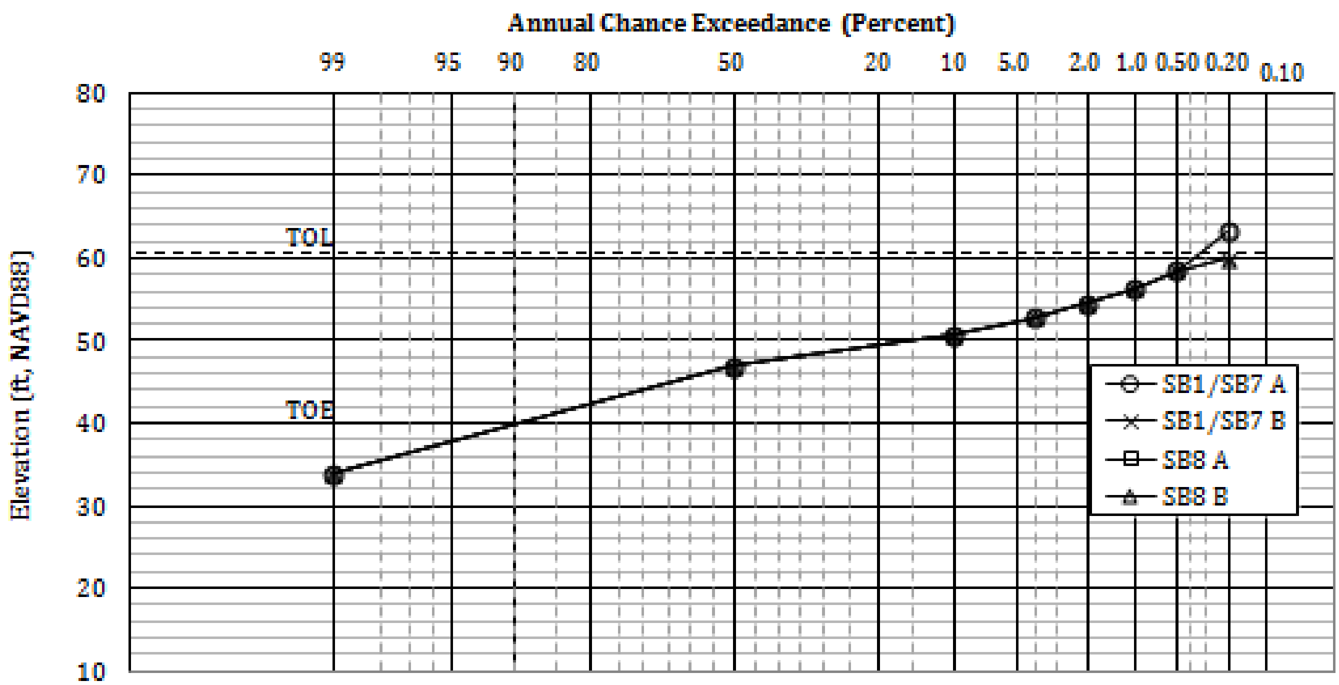
Source:

SUTTER BASIN PILOT FEASBILITY STUDY
SUTTER BASIN, CALIFORNIA

STAGE AND DISCHARGE
FREQUENCY CURVES
FEATHER RIVER AT RM 12.5

U.S ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT





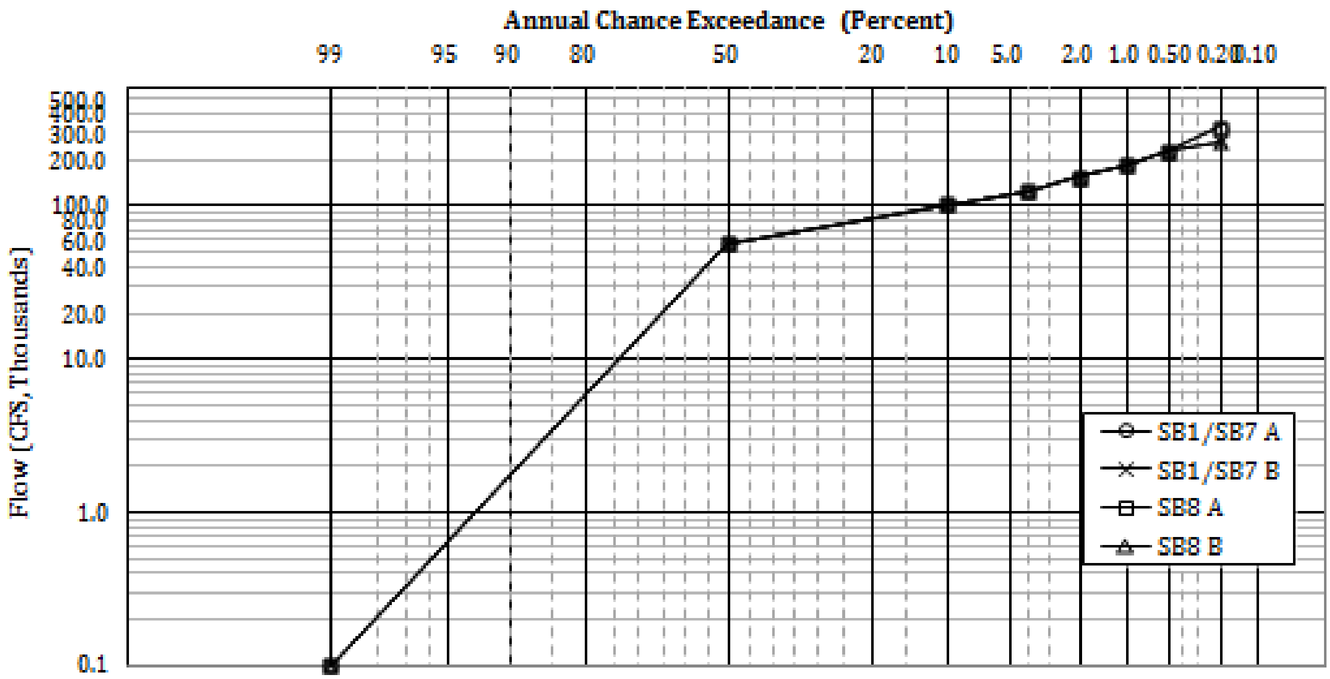
NOTES:
Sutter Bypass at Comp Study RM 83.79 refers to Geotechnical index location SUTTER – 4
TOL = top of levee from 2008 NLDB
TOE = average elevation of bank line adjacent to levee
SB1 – Without Project Conditions
SB7 – Fix in Place Sunset Weir to Laurel Avenue
SB8 – Fix in Place Thermalito to Laurel Avenue
Scenario A – Assumes infinite levee height
Scenario B – Assumes levee overtopping with no failure

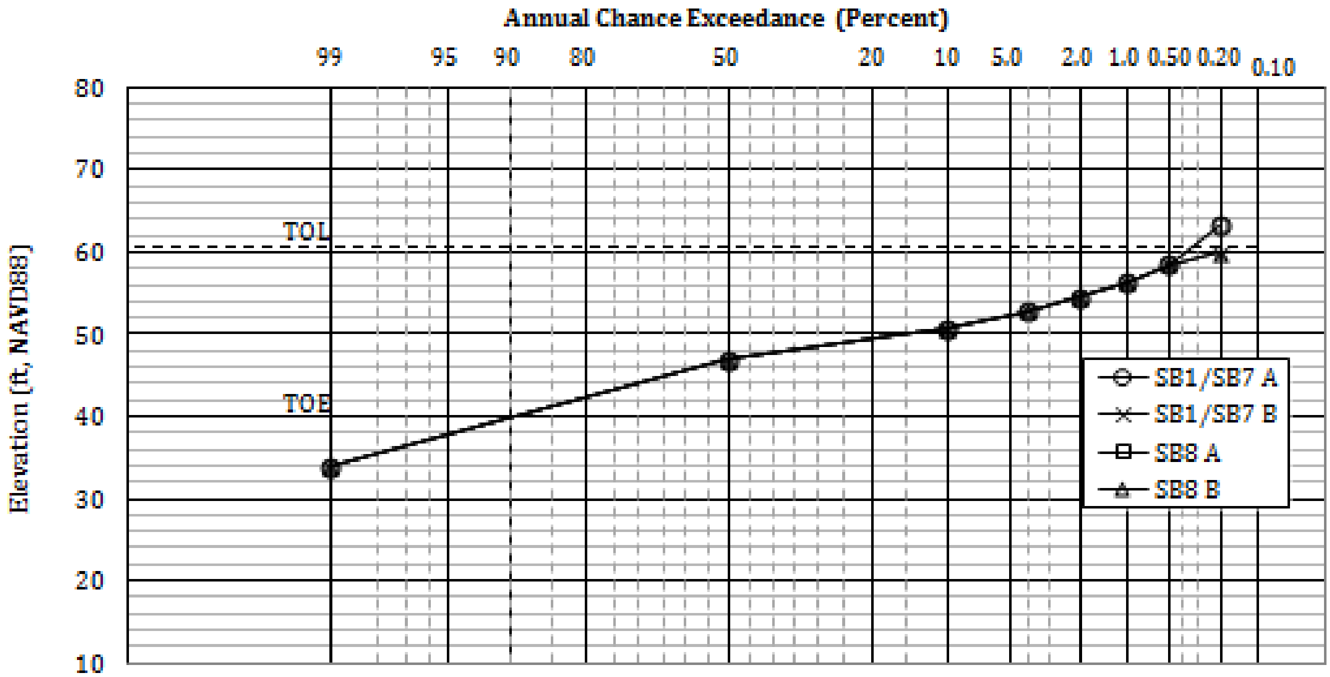
Source:

SUTTER BASIN PILOT FEASBILITY STUDY
SUTTER BASIN, CALIFORNIA

STAGE AND DISCHARGE
FREQUENCY CURVES
SUTTER BYPASS AT RM 83.79

U.S ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT





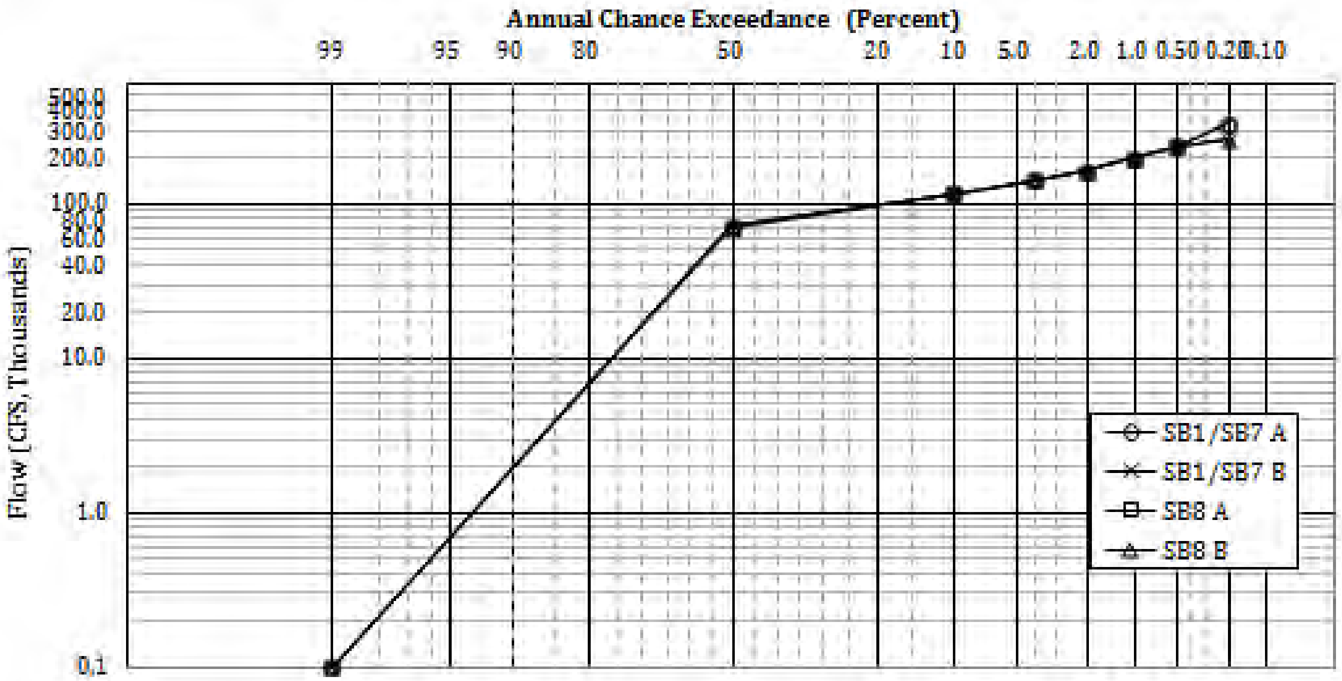
NOTES:
Sutter Bypass at Comp Study RM 81.93 refers to Geotechnical index location SUTTER – 6.2
TOL = top of levee from 2008 NLDB
TOE = average elevation of bank line adjacent to levee
SB1 – Without Project Conditions
SB7 – Fix in Place Sunset Weir to Laurel Avenue
SB8 – Fix in Place Thermalito to Laurel Avenue
Scenario A – Assumes infinite levee height
Scenario B – Assumes levee overtopping with no failure

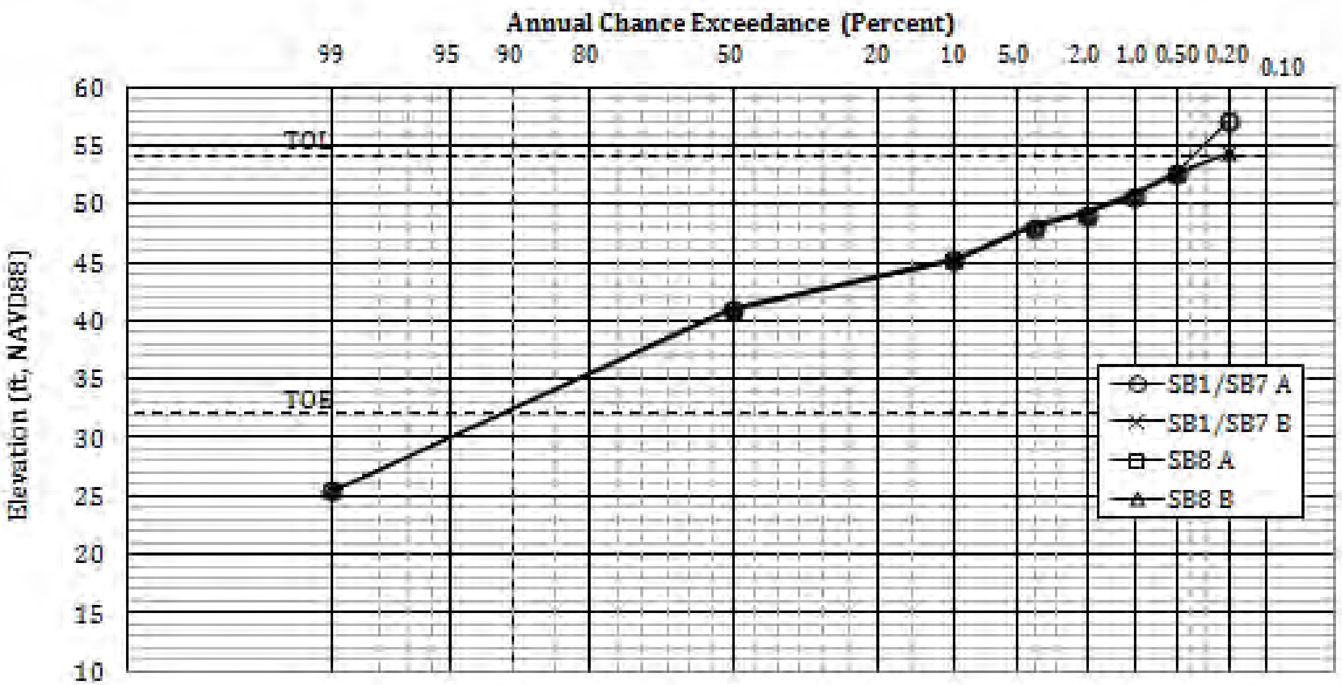
Source:

SUTTER BASIN PILOT FEASBILITY STUDY
SUTTER BASIN, CALIFORNIA

STAGE AND DISCHARGE
FREQUENCY CURVES
SUTTER BYPASS AT RM 81.93

U.S ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT





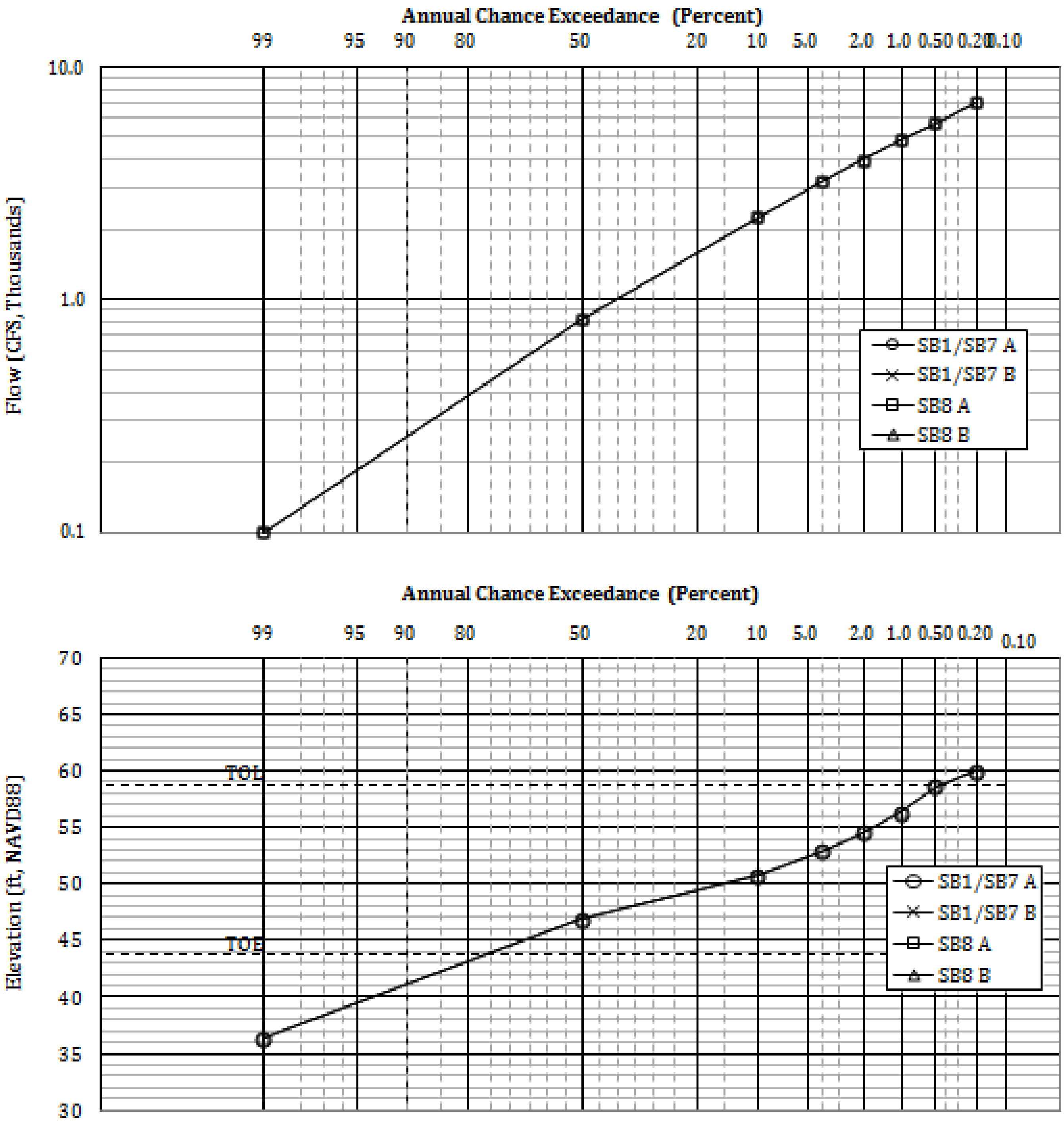
NOTES:
Sutter Bypass at Comp Study RM 71.65 refers to Geotechnical index location SUTTER – 17.3
TOL = top of levee from 2008 NLDB
TOE = average elevation of bank line adjacent to levee
SB1 – Without Project Conditions
SB7 – Fix in Place Sunset Weir to Laurel Avenue
SB8 – Fix in Place Thermalito to Laurel Avenue
Scenario A – Assumes infinite levee height
Scenario B – Assumes levee overtopping with no failure

Source:

SUTTER BASIN PILOT FEASBILITY STUDY
SUTTER BASIN, CALIFORNIA

STAGE AND DISCHARGE
FREQUENCY CURVES
SUTTER BYPASS AT RM 71.65

U.S ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT



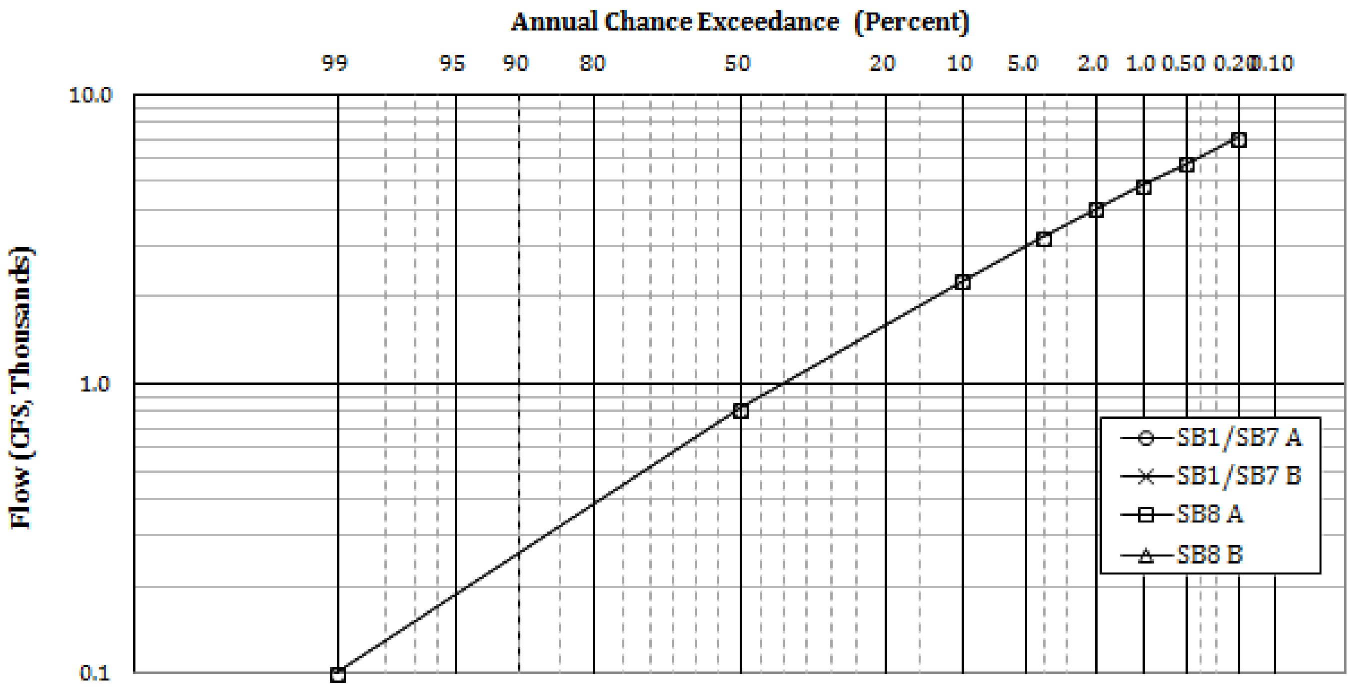
NOTES:
Wadsworth Canal at RM 0.81 refers to Geotechnical index location
WADSWORTH – 0.84
TOL = top of levee from 2008 NLDB
TOE = average elevation of bank line adjacent to levee
SB1 – Without Project Conditions
SB7 – Fix in Place Sunset Weir to Laurel Avenue
SB8 – Fix in Place Thermalito to Laurel Avenue
Scenario A – Assumes infinite levee height
Scenario B – Assumes levee overtopping with no failure

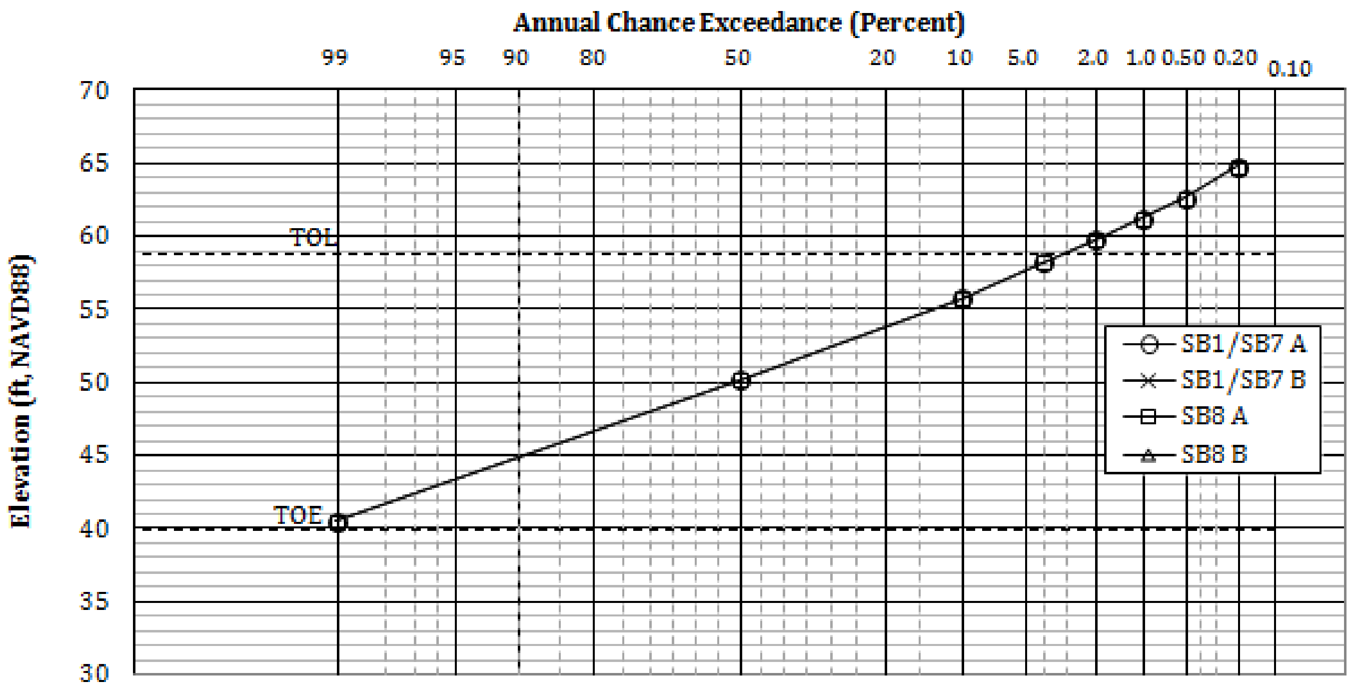
Source:

SUTTER BASIN PILOT FEASBILITY STUDY
SUTTER BASIN, CALIFORNIA

STAGE AND DISCHARGE
FREQUENCY CURVES
WADSWORTH CANAL AT RM 0.81

U.S ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT





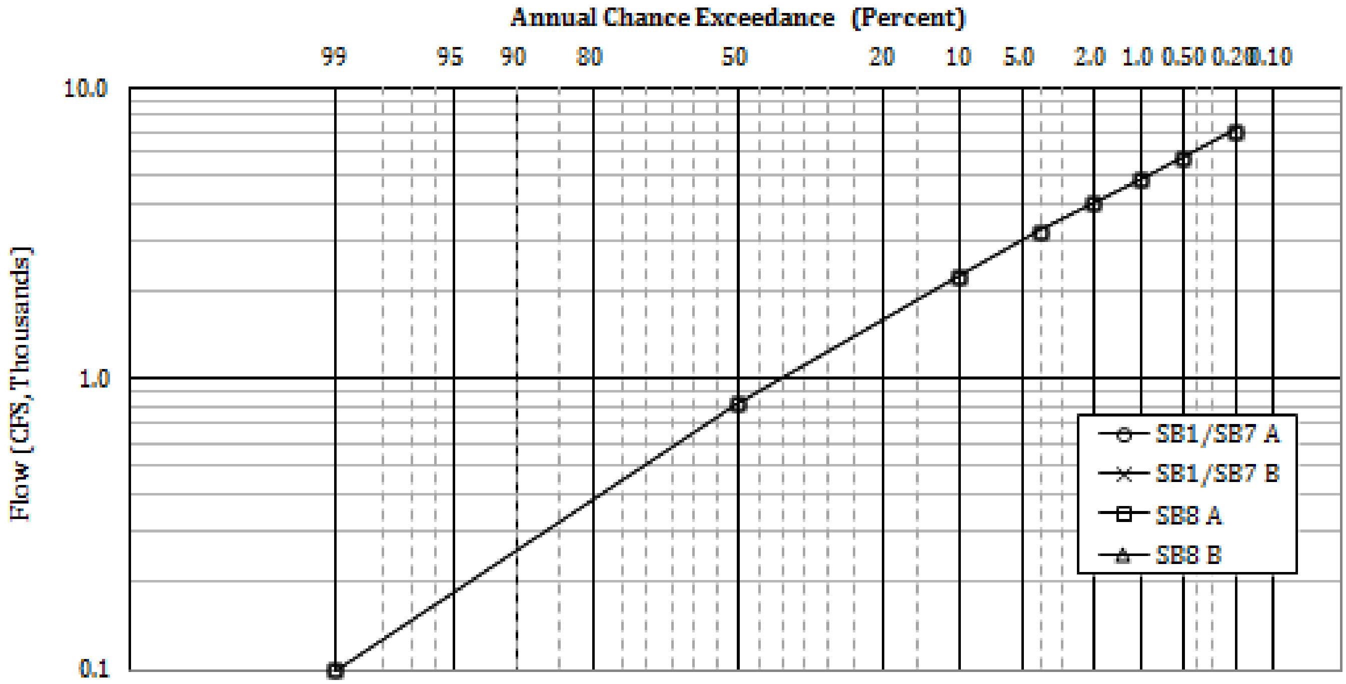
NOTES:
Wadsworth Canal at RM 4.54 defines the upstream capacity prior to overtopping
TOL = top of levee from 2008 NLDB
TOE = average elevation of bank line adjacent to levee
SB1 – Without Project Conditions
SB7 – Fix in Place Sunset Weir to Laurel Avenue
SB8 – Fix in Place Thermalito to Laurel Avenue
Scenario A – Assumes infinite levee height
Scenario B – Assumes levee overtopping with no failure

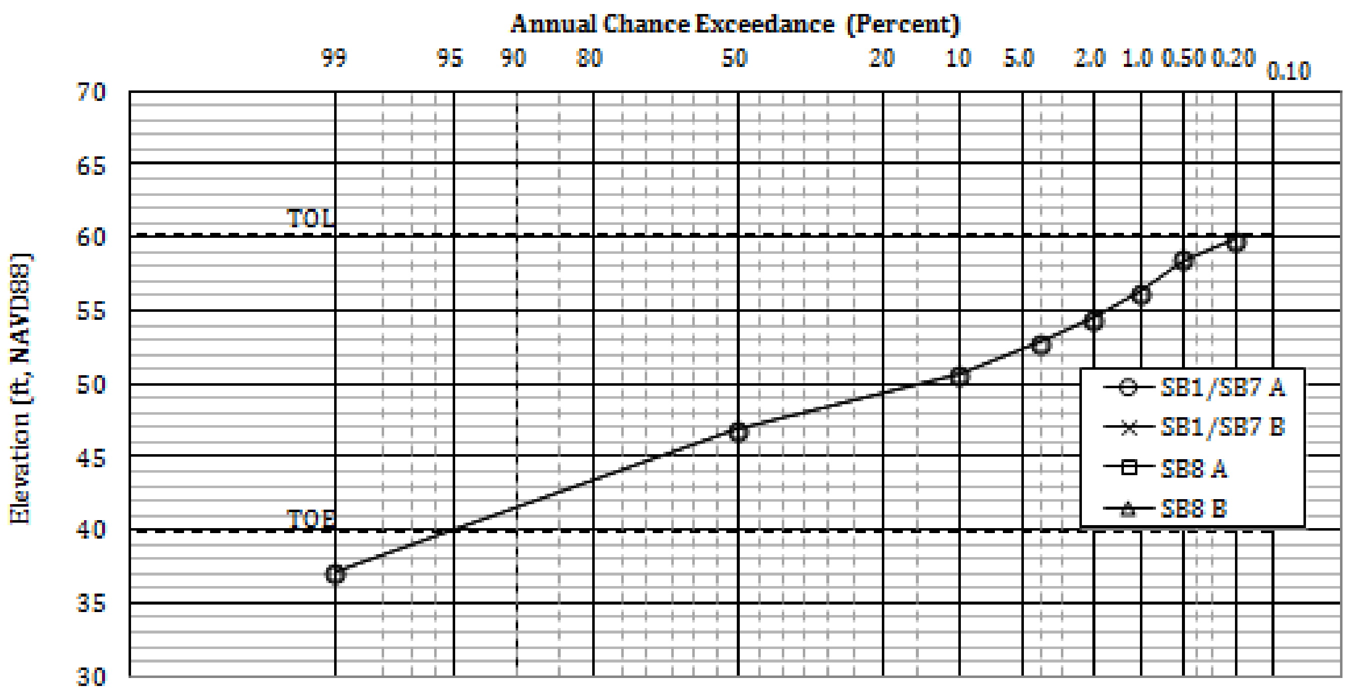
Source:

SUTTER BASIN PILOT FEASBILITY STUDY
SUTTER BASIN, CALIFORNIA

STAGE AND DISCHARGE
FREQUENCY CURVES
WADSWORTH CANAL AT RM 4.54

U.S ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT





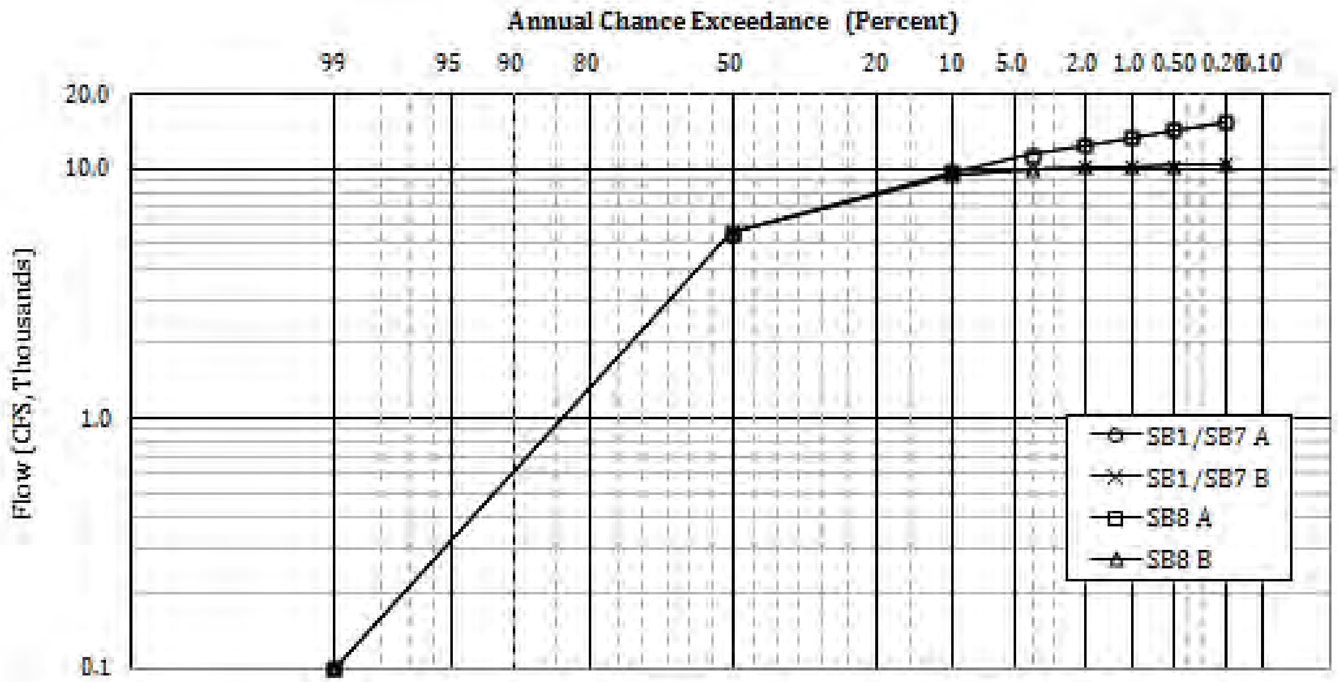
NOTES:
Wadsworth Canal at Comp Study RM 0.25 refers to Geotechnical Index location WADSWORTH – 0.5
TOL = top of levee from 2008 NLDB
TOE = average elevation of bank line adjacent to levee
SB1 – Without Project Conditions
SB7 – Fix in Place Sunset Weir to Laurel Avenue
SB8 – Fix in Place Thermalito to Laurel Avenue
Scenario A – Assumes infinite levee height
Scenario B – Assumes levee overtopping with no failure

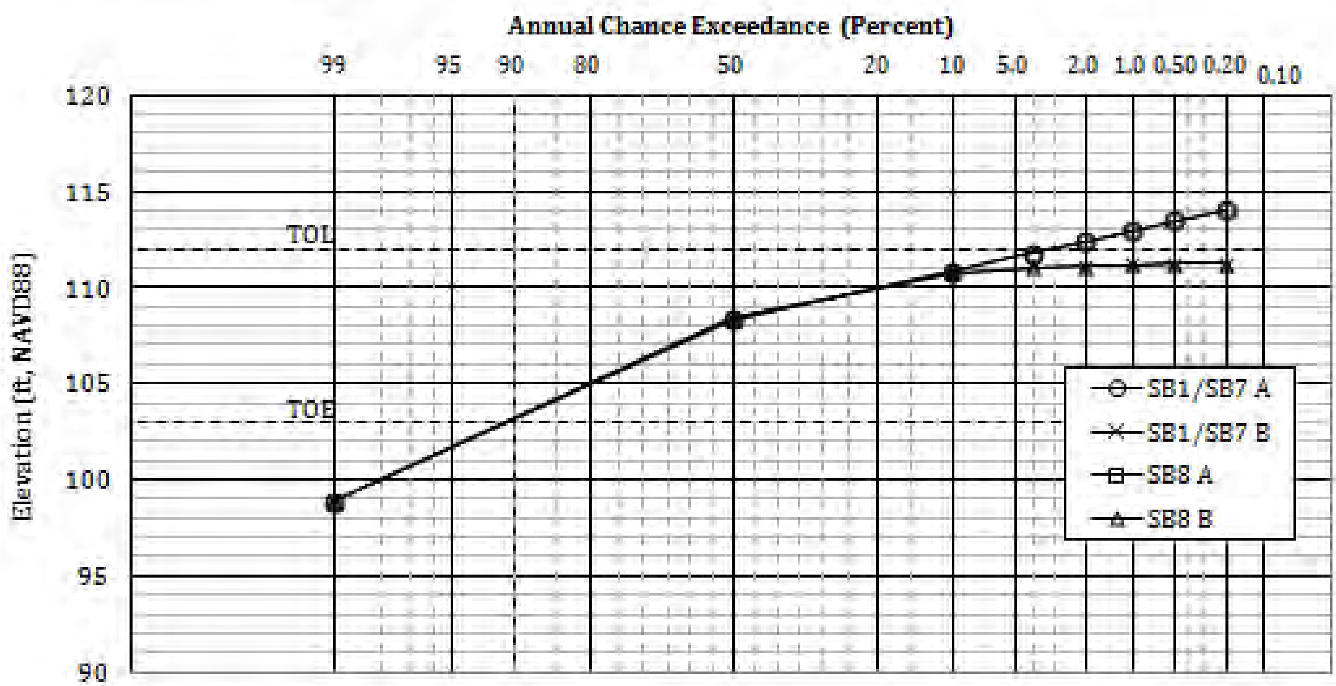
Source:

SUTTER BASIN PILOT FEASBILITY STUDY
SUTTER BASIN, CALIFORNIA

STAGE AND DISCHARGE FREQUENCY CURVES WADSWORTH CANAL AT RM 0.25

U.S ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT





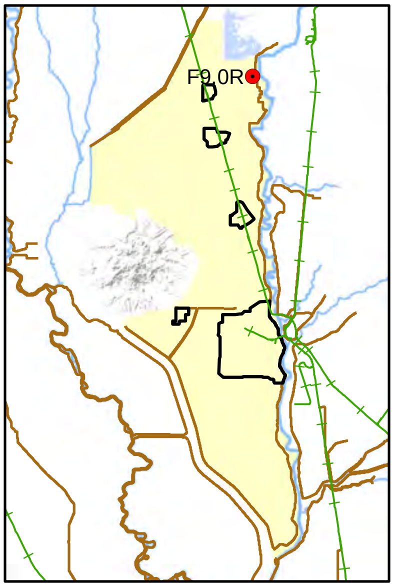
NOTES:
Cherokee Canal at DWR HEC-RAS RM 12.529 refers to Geotechnical index location CHEROKEE – 9.5
TOL = top of levee from 2008 NLDB
TOE = average elevation of bank line adjacent to levee
SB1 – Without Project Conditions
SB7 – Fix in Place Sunset Weir to Laurel Avenue
SB8 – Fix in Place Thermalito to Laurel Avenue
Scenario A – Assumes infinite levee height
Scenario B – Assumes levee overtopping with no failure

Source:

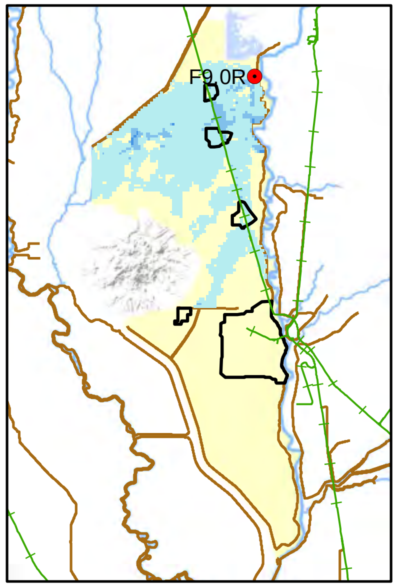
SUTTER BASIN PILOT FEASBILITY STUDY
SUTTER BASIN, CALIFORNIA

STAGE AND DISCHARGE
FREQUENCY CURVES
CHEROKEE CANAL AT RM 12.529

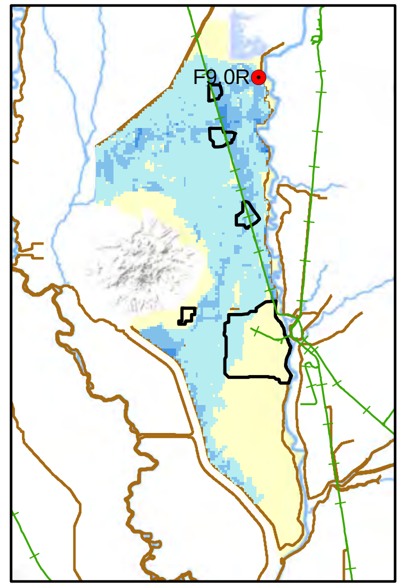
U.S ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT



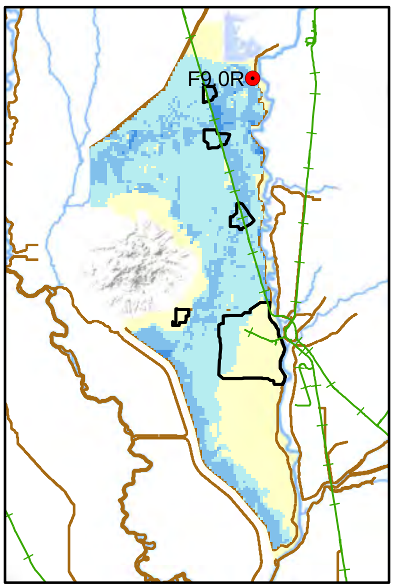
50% (1/2) ACE



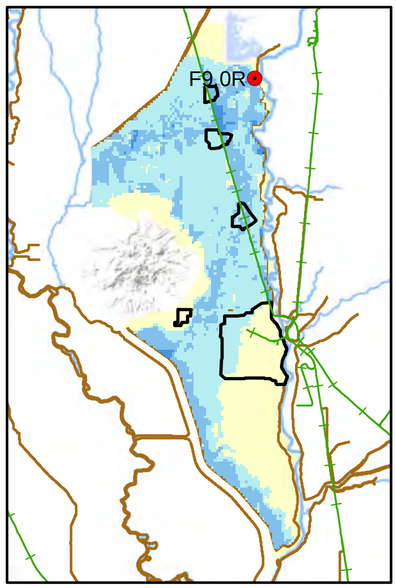
10% (1/10) ACE



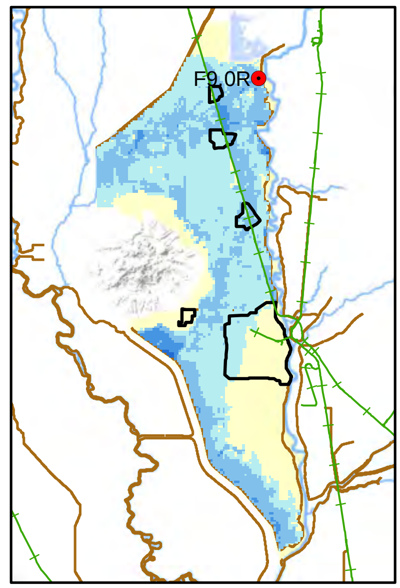
4% (1/25) ACE



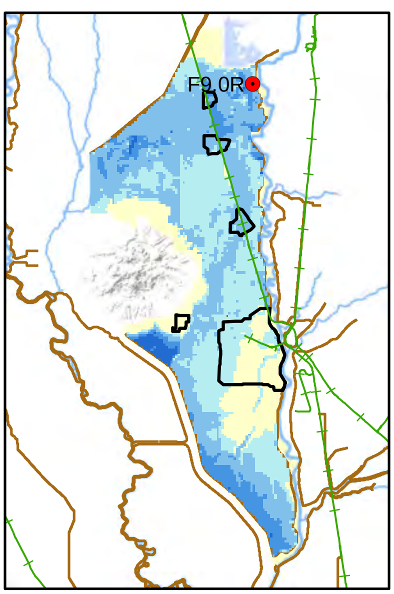
2% (1/50) ACE



1% (1/100) ACE



0.5% (1/200) ACE



0.2% (1/500) ACE

Depth

(ft)

- less than 2
- 2 to 6
- 6 to 10
- 10 to 15
- 15 to 20
- greater than 20

Railroad

Miles
0 10 20

NOTE: MAP DEPICTS OVERTOPPING WITHOUT FAILURE IN REACHES WITHOUT A BREACH

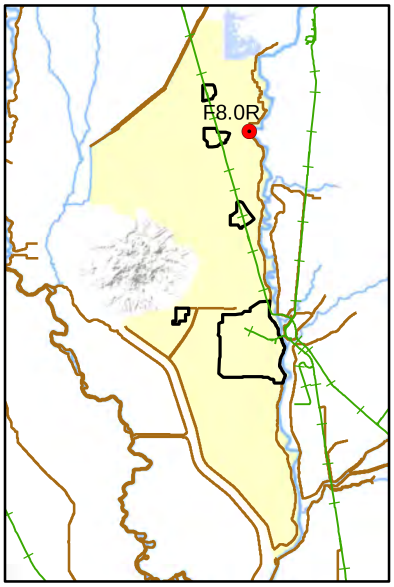
SUTTER BASIN PILOT FEASIBILITY STUDY
SUTTER BASIN, CALIFORNIA

BREACH SIMULATION
ALTERNATIVE SB-1
FEATHER RIVER WEST LEVEE
LOCATION F9.0R

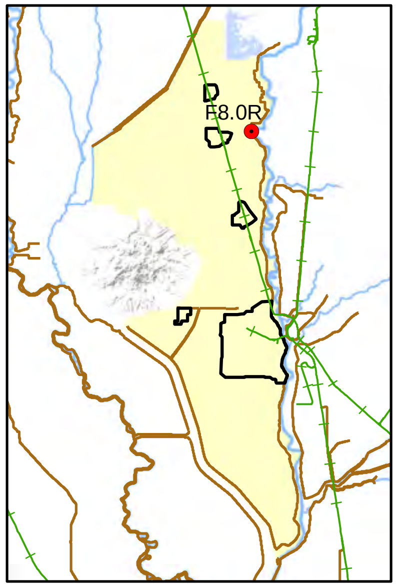
U.S. ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT

Prepared by T. Hatch

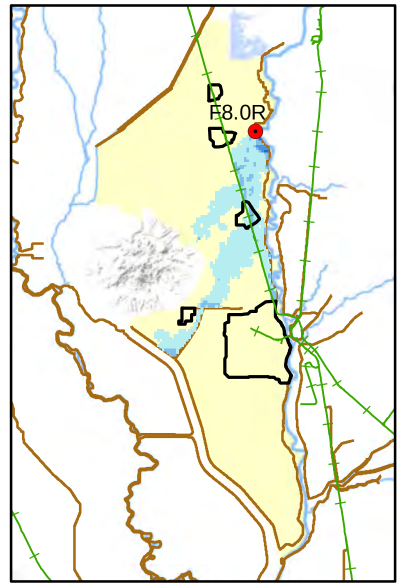
FEB 2013



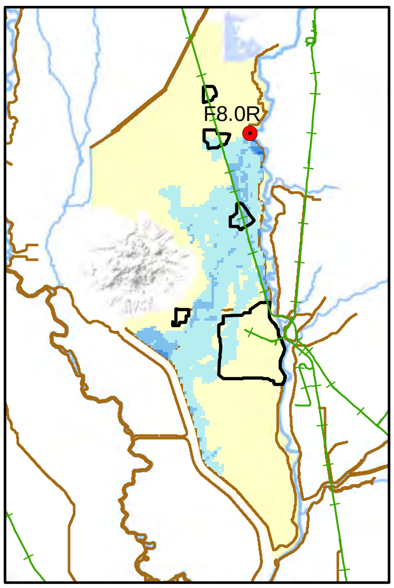
50% (1/2) ACE



10% (1/10) ACE



4% (1/25) ACE



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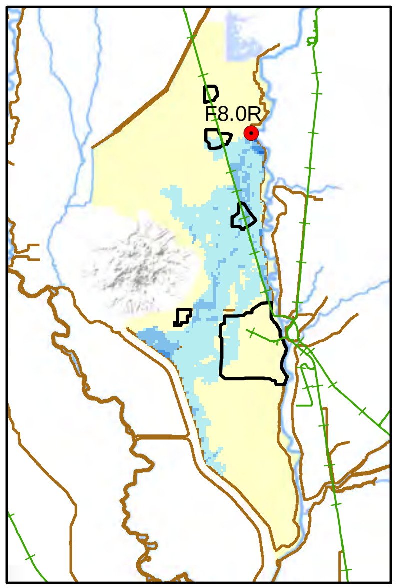

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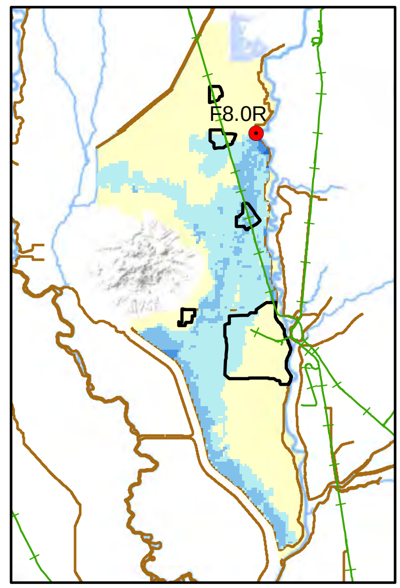

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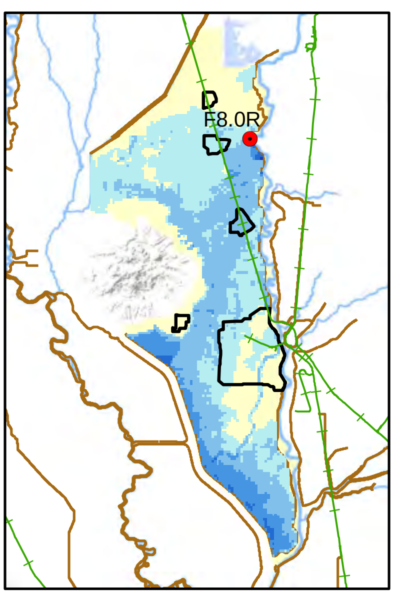


0.2% (1/500) ACE

Depth

(ft)

- less than 2
- 2 to 6
- 6 to 10
- 10 to 15
- 15 to 20
- greater than 20

Railroad

Miles
0 10 20

NOTE: MAP DEPICTS OVERTOPPING WITHOUT FAILURE IN REACHES WITHOUT A BREACH

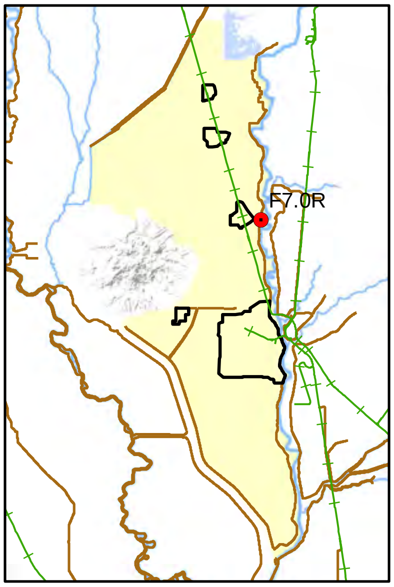
SUTTER BASIN PILOT FEASIBILITY STUDY
SUTTER BASIN, CALIFORNIA

BREACH SIMULATION
ALTERNATIVE SB-1
FEATHER RIVER WEST LEVEE
LOCATION F8.0R

U.S. ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT

Prepared by T. Hatch

FEB 2013



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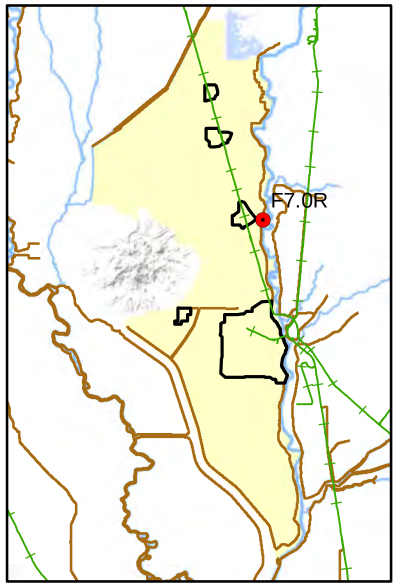
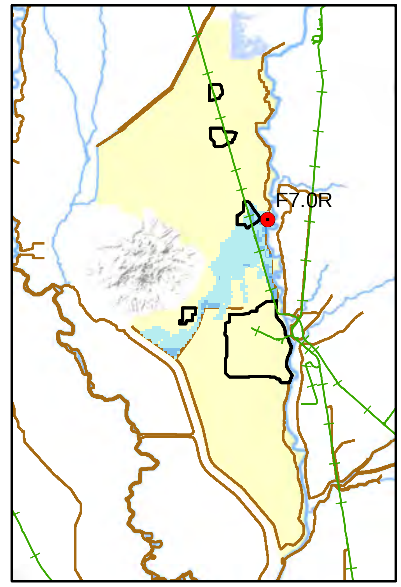


10% (1/10) ACE



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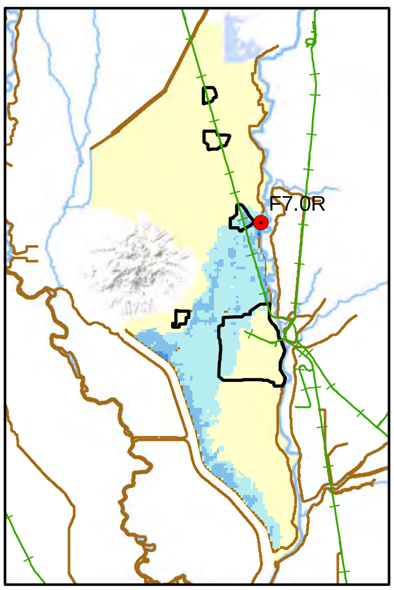
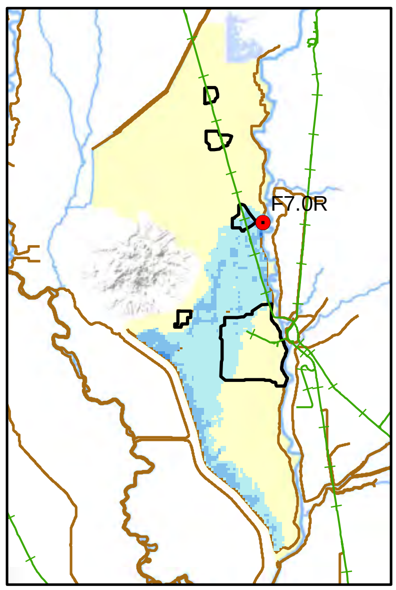


2% (1/50) ACE



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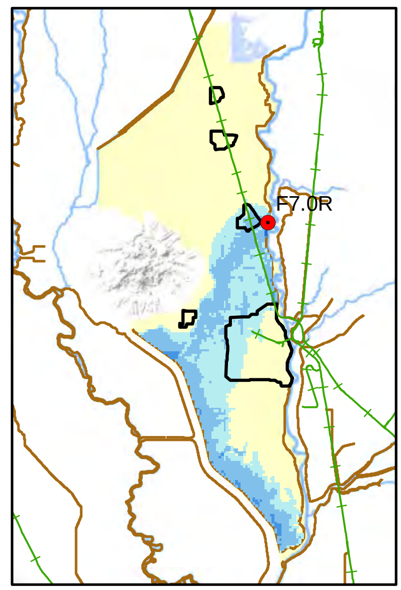

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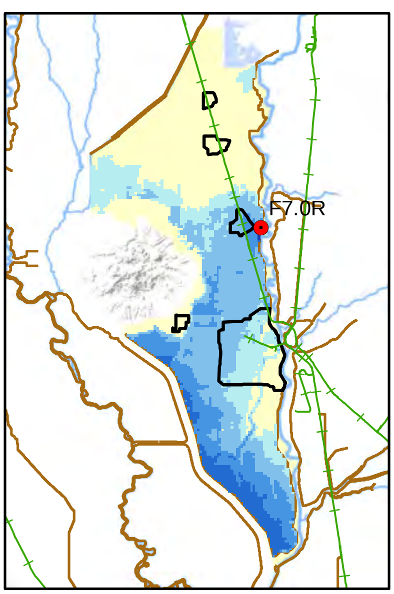


0.2% (1/500) ACE

Depth

(ft)

- less than 2
- 2 to 6
- 6 to 10
- 10 to 15
- 15 to 20
- greater than 20

Railroad

Miles
0 10 20

NOTE: MAP DEPICTS OVERTOPPING WITHOUT FAILURE IN REACHES WITHOUT A BREACH

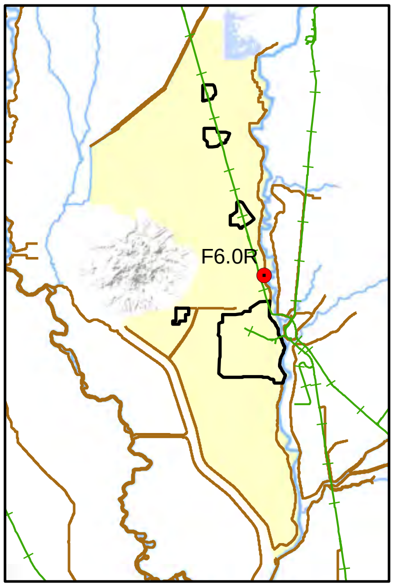
SUTTER BASIN PILOT FEASIBILITY STUDY
SUTTER BASIN, CALIFORNIA

BREACH SIMULATION
ALTERNATIVE SB-1
FEATHER RIVER WEST LEVEE
LOCATION F7.0R

U.S. ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT

Prepared by T. Hatch

FEB 2013



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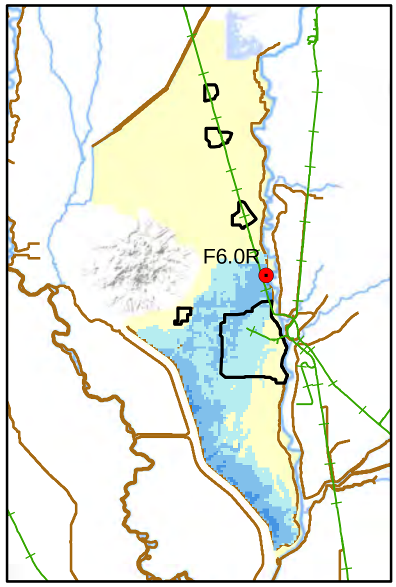
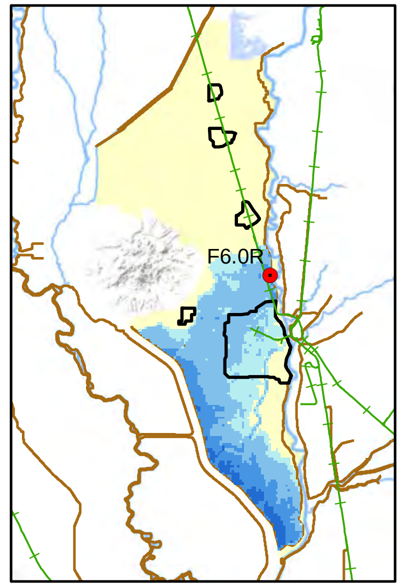
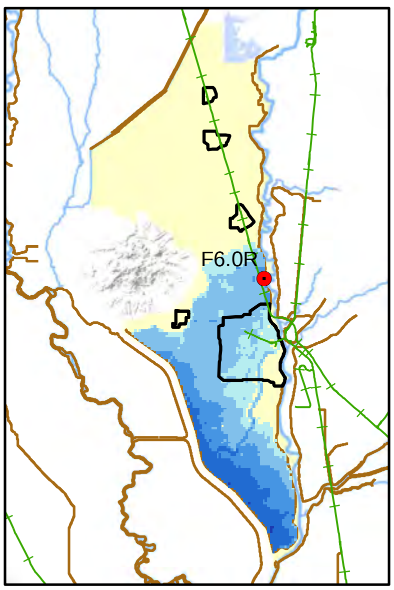


10% (1/10) ACE



4% (1/25) ACE



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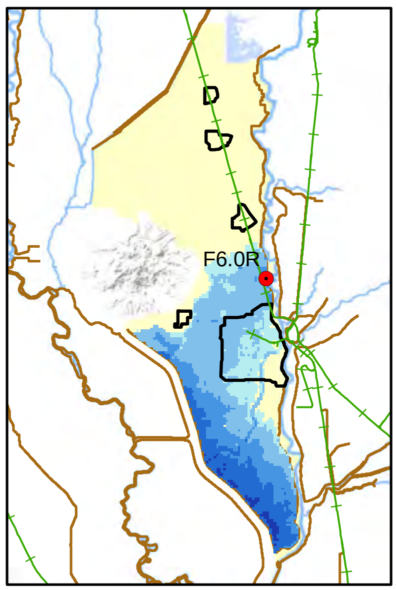
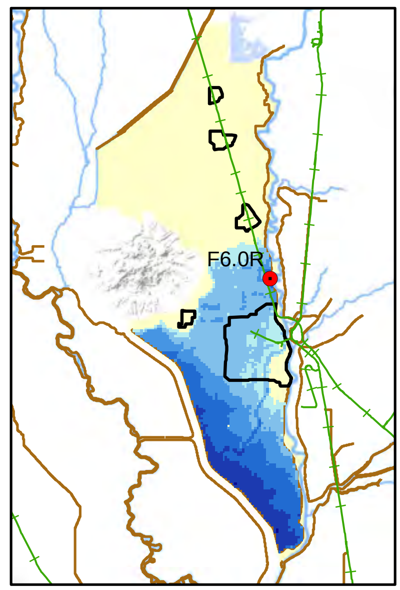


1% (1/100) ACE



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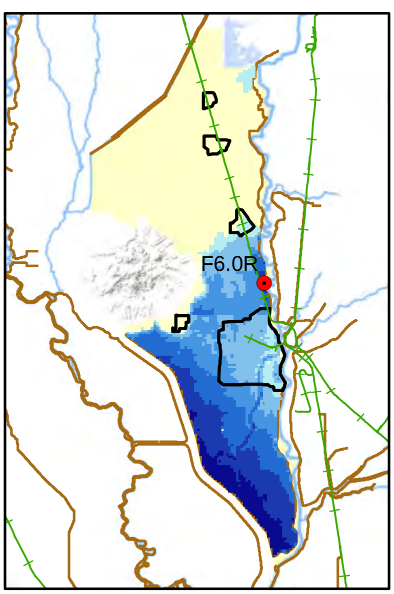


0.2% (1/500) ACE

Depth

(ft)

- less than 2
- 2 to 6
- 6 to 10
- 10 to 15
- 15 to 20
- greater than 20

Railroad

Miles
0 10 20

NOTE: MAP DEPICTS OVERTOPPING WITHOUT FAILURE IN REACHES WITHOUT A BREACH

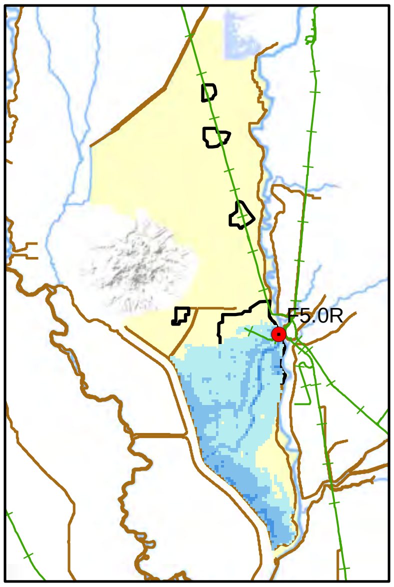
SUTTER BASIN PILOT FEASIBILITY STUDY
SUTTER BASIN, CALIFORNIA

BREACH SIMULATION
ALTERNATIVE SB-1
FEATHER RIVER WEST LEVEE
LOCATION F6.0R

U.S. ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT

Prepared by T. Hatch

FEB 2013



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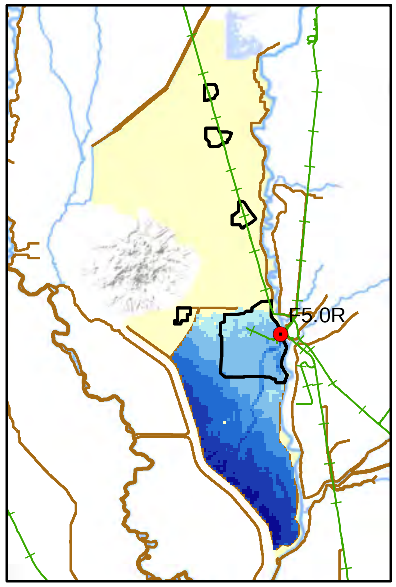
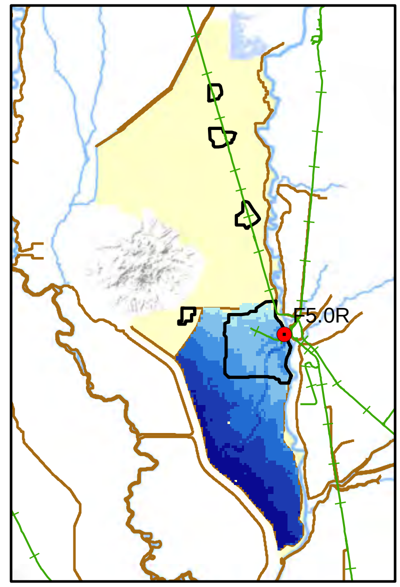
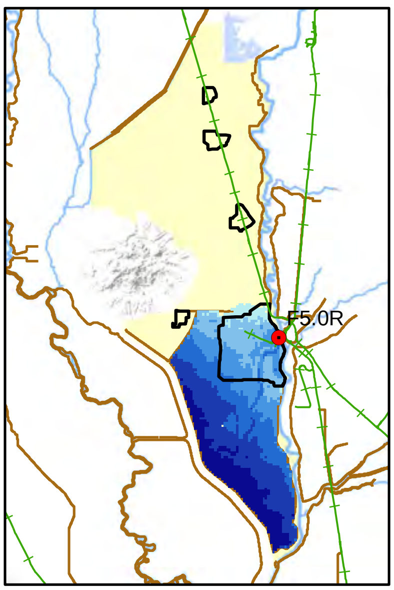


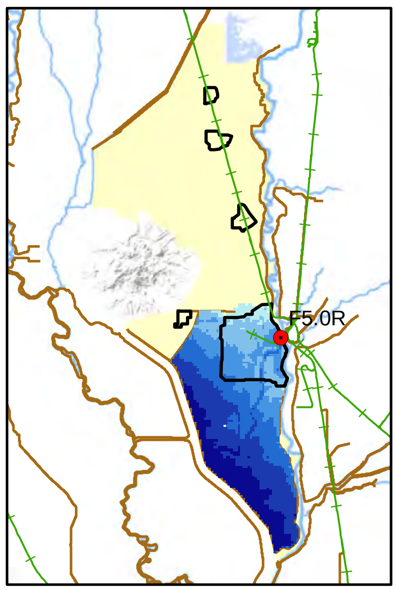
10% (1/10) ACE



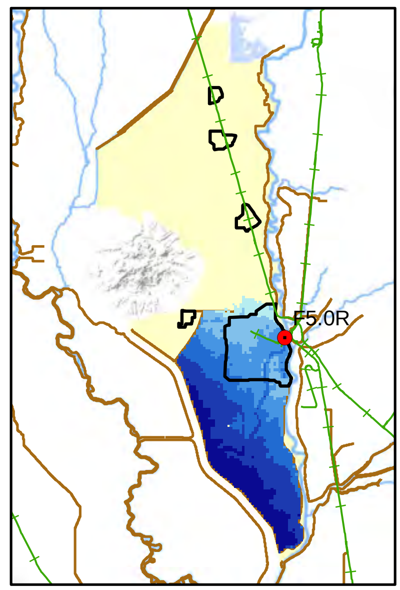
4% (1/25) ACE



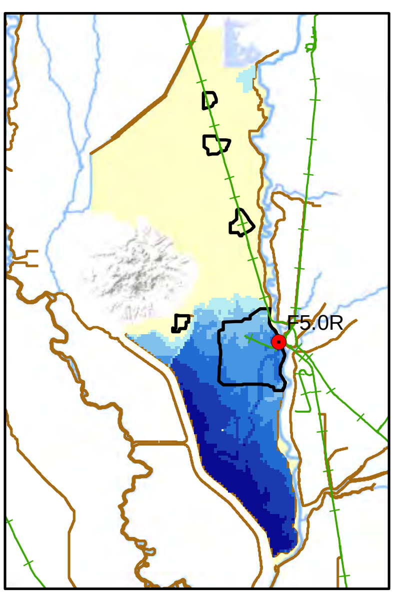
2% (1/50) ACE



1% (1/100) ACE



0.5% (1/200) ACE



0.2% (1/500) ACE

Depth

(ft)

- less than 2
- 2 to 6
- 6 to 10
- 10 to 15
- 15 to 20
- greater than 20

Railroad

0 10 20 Miles

N

NOTE: MAP DEPICTS OVERTOPPING WITHOUT FAILURE IN REACHES WITHOUT A BREACH

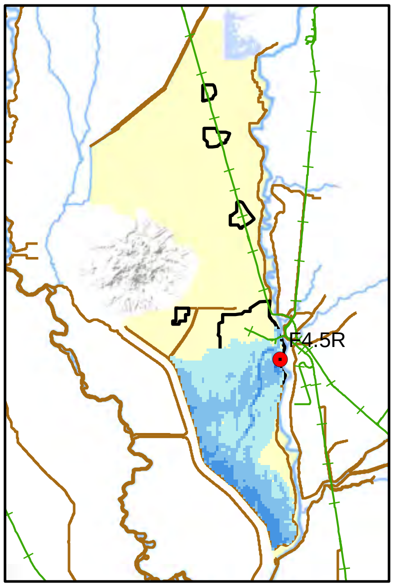
SUTTER BASIN PILOT FEASIBILITY STUDY
SUTTER BASIN, CALIFORNIA

BREACH SIMULATION ALTERNATIVE SB-1 FEATHER RIVER WEST LEVEE LOCATION F5.0R

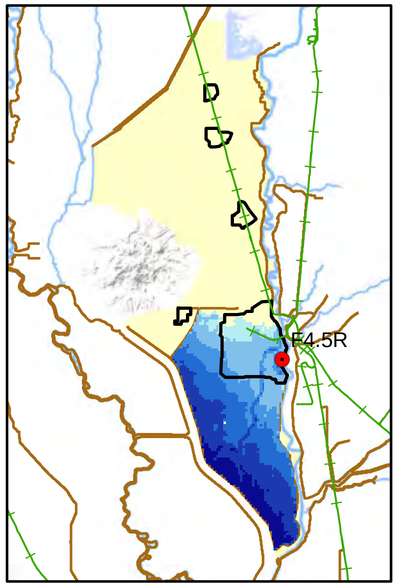
U.S. ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT

Prepared by T. Hatch

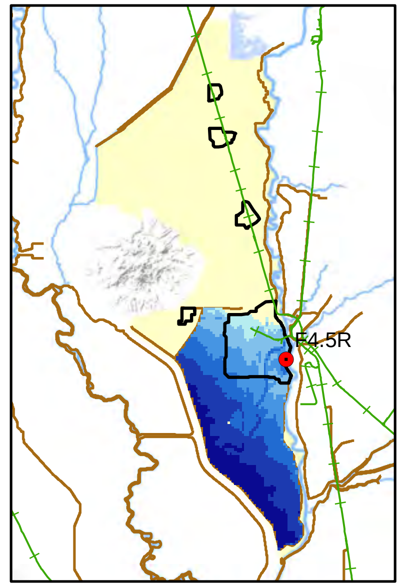
FEB 2013



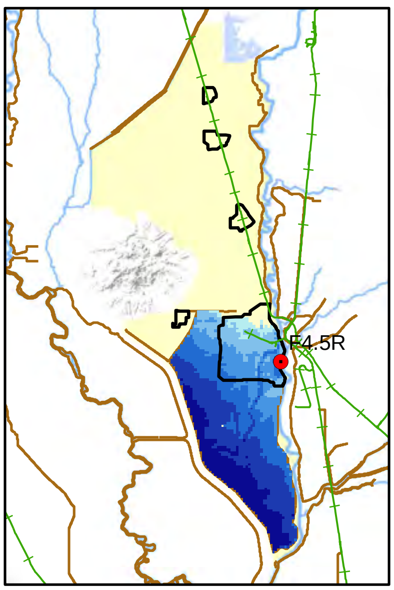
50% (1/2) ACE



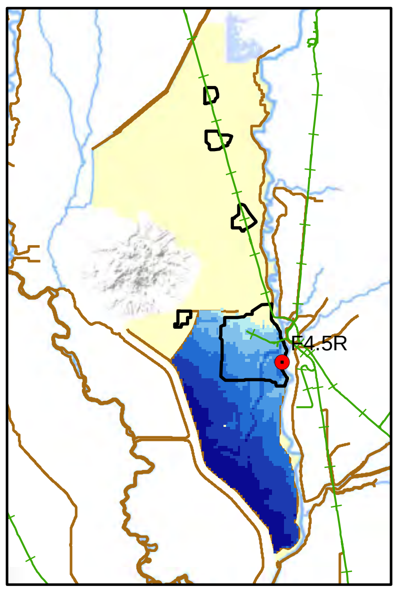
10% (1/10) ACE



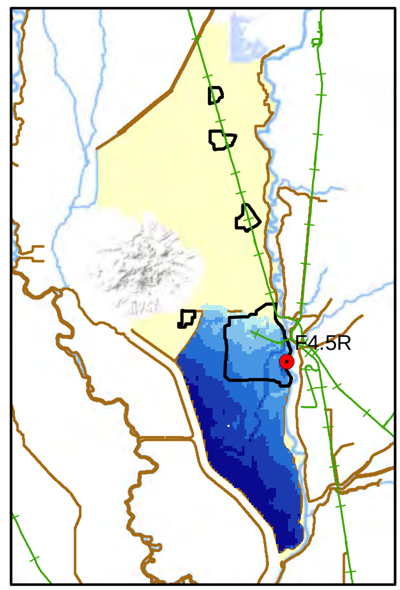
4% (1/25) ACE



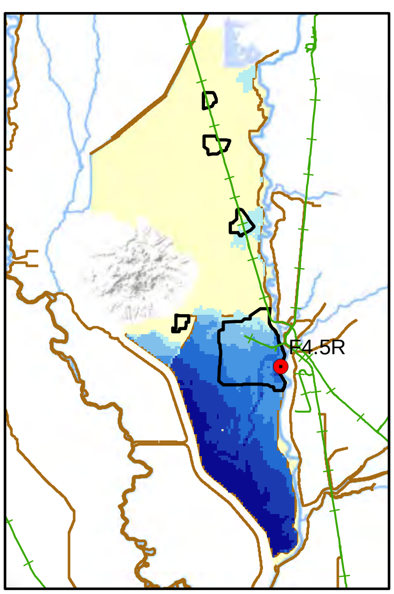
2% (1/50) ACE



1% (1/100) ACE



0.5% (1/200) ACE



0.2% (1/500) ACE

Depth

(ft)

- less than 2
- 2 to 6
- 6 to 10
- 10 to 15
- 15 to 20
- greater than 20

Railroad

0 10 20 Miles

NOTE: MAP DEPICTS OVERTOPPING WITHOUT FAILURE IN REACHES WITHOUT A BREACH

SUTTER BASIN PILOT FEASIBILITY STUDY
SUTTER BASIN, CALIFORNIA

BREACH SIMULATION ALTERNATIVE SB-1 FEATHER RIVER WEST LEVEE LOCATION F4.5R

U.S. ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT

Prepared by T. Hatch

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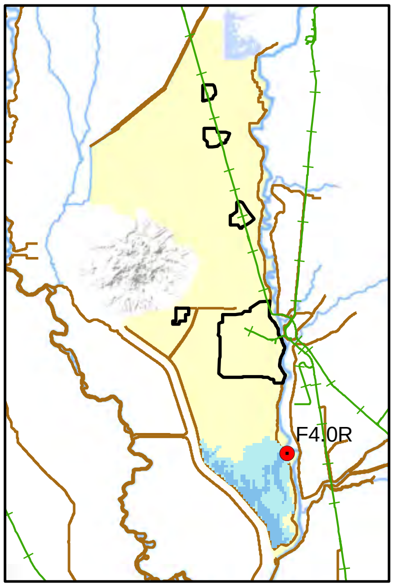
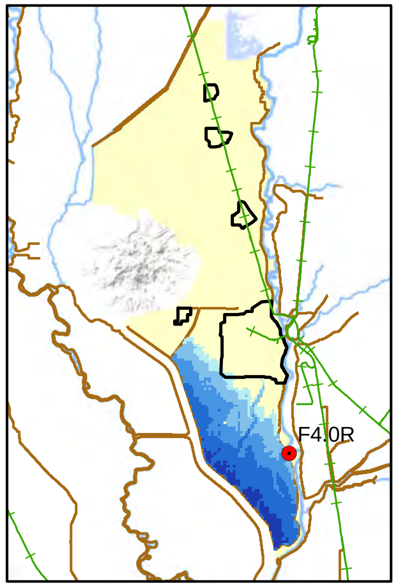
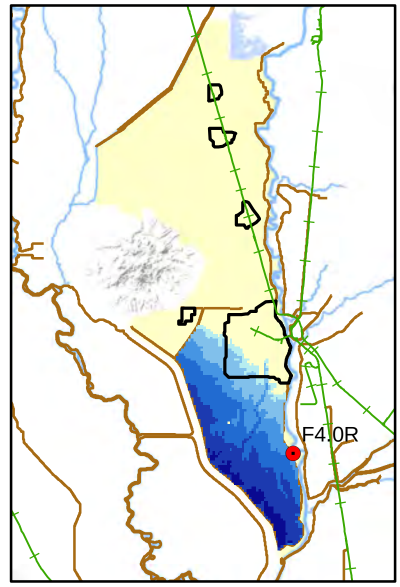


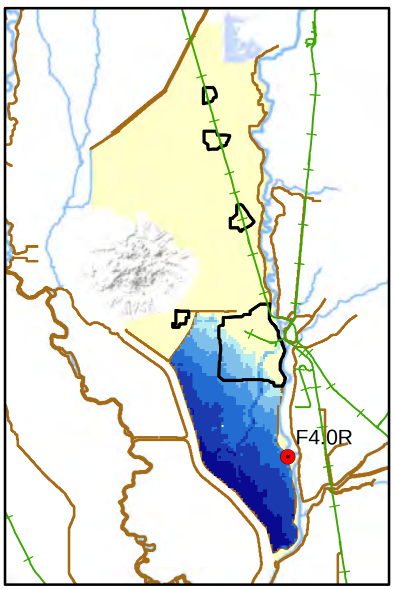
50% (1/2) ACE



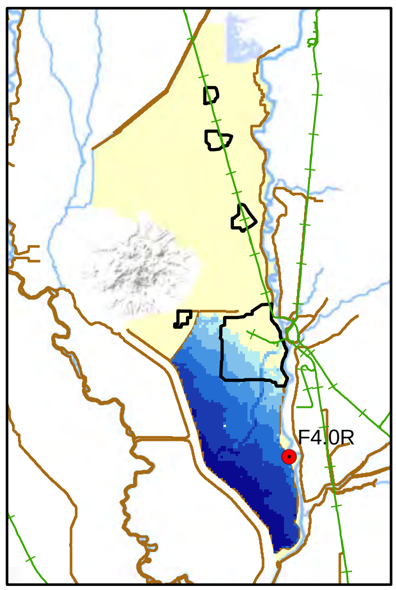
10% (1/10) ACE



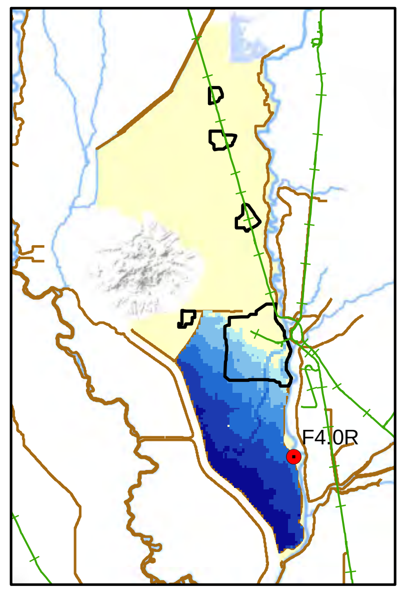
4% (1/25) ACE



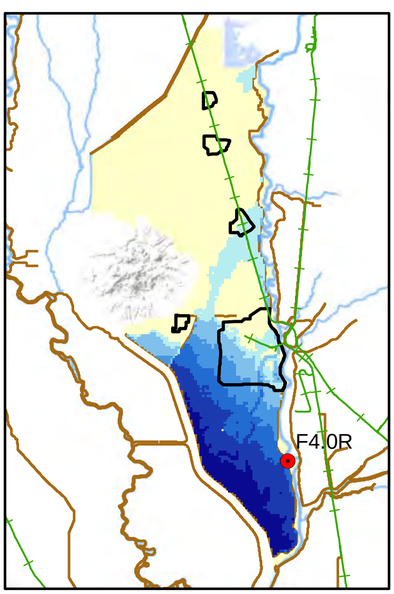
2% (1/50) ACE



1% (1/100) ACE



0.5% (1/200) ACE



0.2% (1/500) ACE

Depth

(ft)

- less than 2
- 2 to 6
- 6 to 10
- 10 to 15
- 15 to 20
- greater than 20

Railroad

Miles
0 10 20

NOTE: MAP DEPICTS OVERTOPPING WITHOUT FAILURE IN REACHES WITHOUT A BREACH

SUTTER BASIN PILOT FEASIBILITY STUDY
SUTTER BASIN, CALIFORNIA

BREACH SIMULATION ALTERNATIVE SB-1 FEATHER RIVER WEST LEVEE LOCATION F4.0R

U.S. ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT

Prepared by T. Hatch

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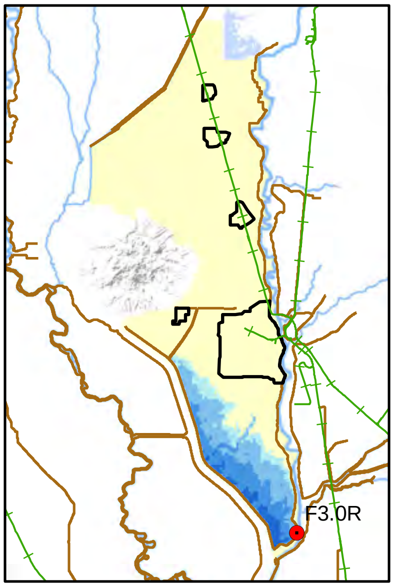
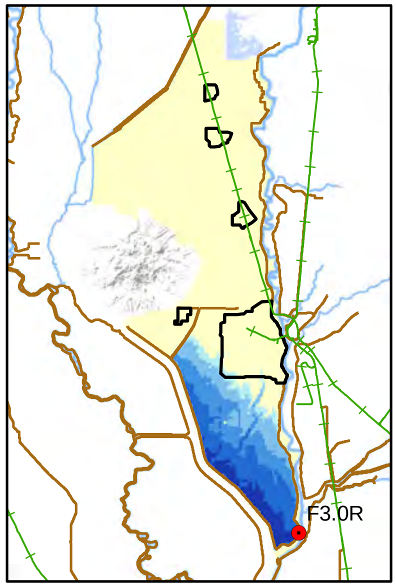
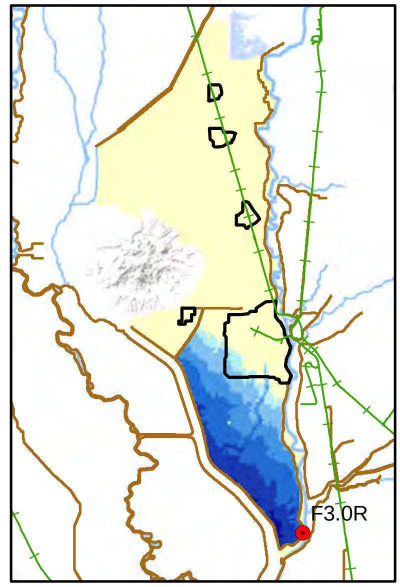


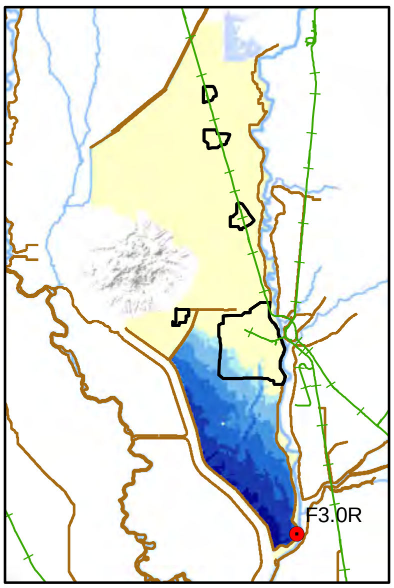
50% (1/2) ACE



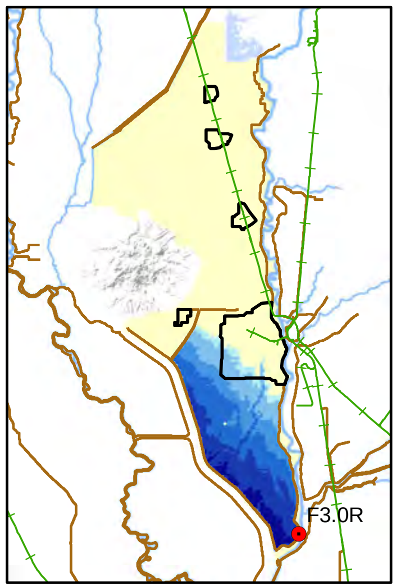
10% (1/10) ACE



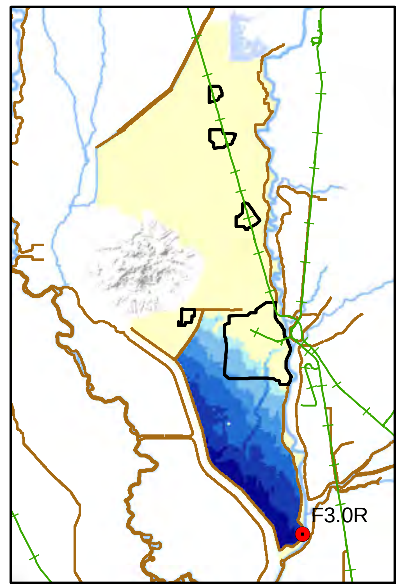
4% (1/25) ACE



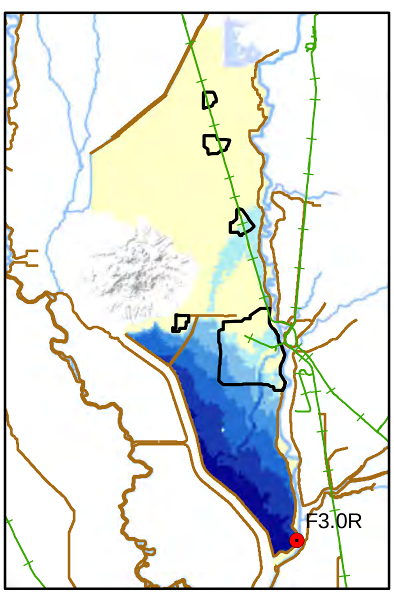
2% (1/50) ACE



1% (1/100) ACE



0.5% (1/200) ACE



0.2% (1/500) ACE

Depth

(ft)

- less than 2
- 2 to 6
- 6 to 10
- 10 to 15
- 15 to 20
- greater than 25

Railroad

Miles
0 10 20

NOTE: MAP DEPICTS OVERTOPPING WITHOUT FAILURE IN REACHES WITHOUT A BREACH

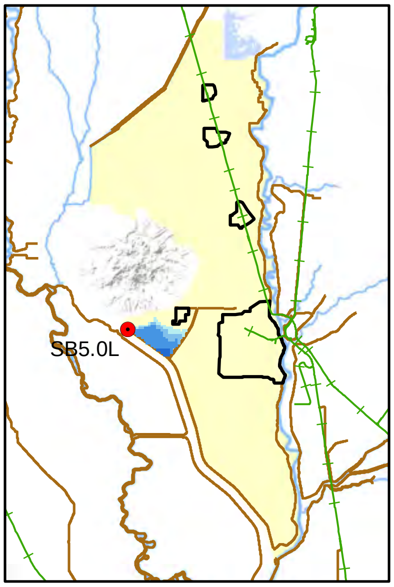
SUTTER BASIN PILOT FEASIBILITY STUDY
SUTTER BASIN, CALIFORNIA

BREACH SIMULATION ALTERNATIVE SB-1 FEATHER RIVER WEST LEVEE LOCATION F3.0R

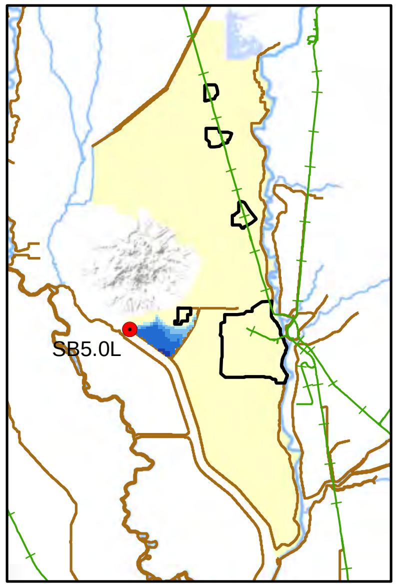
U.S. ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT

Prepared by T. Hatch

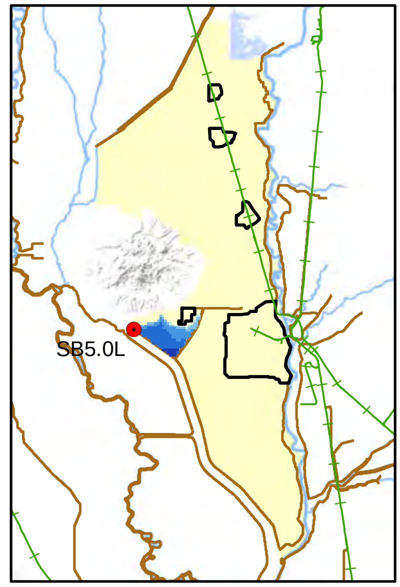
FEB 2013



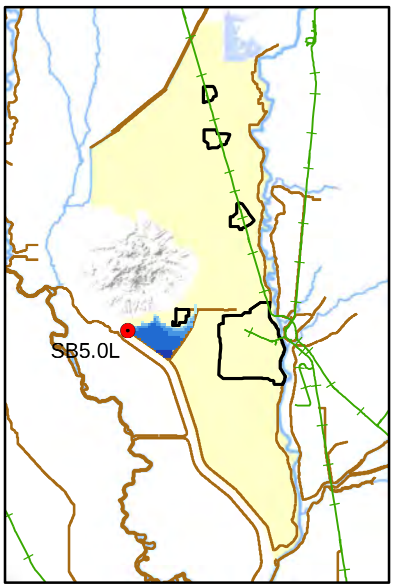
50% (1/2) ACE



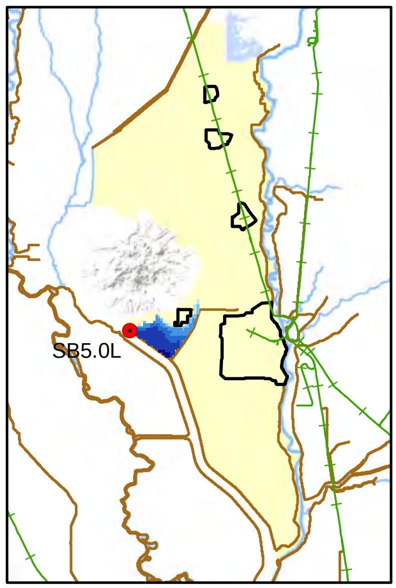
10% (1/10) ACE



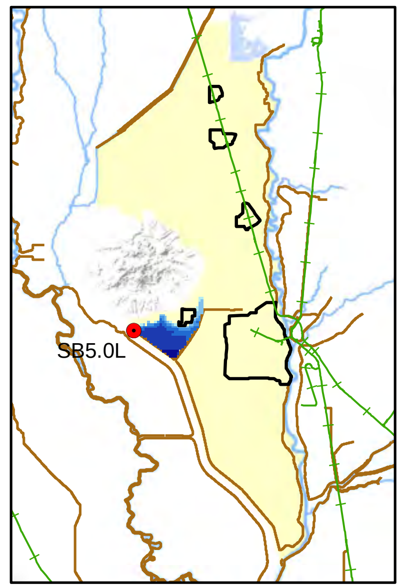
4% (1/25) ACE



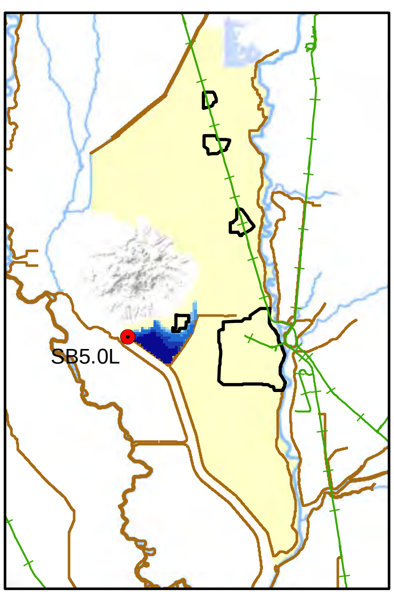
2% (1/50) ACE



1% (1/100) ACE



0.5% (1/200) ACE



0.2% (1/500) ACE

Depth

(ft)

- less than 2
- 2 to 6
- 6 to 10
- 10 to 15
- 15 to 20
- greater than 20

Railroad

0 10 20 Miles

NOTE: MAP DEPICTS OVERTOPPING WITHOUT FAILURE IN REACHES WITHOUT A BREACH

SUTTER BASIN PILOT FEASIBILITY STUDY
SUTTER BASIN, CALIFORNIA

BREACH SIMULATION ALTERNATIVE SB-1 SUTTER BYPASS EAST LEVEE LOCATION SB5.0L

U.S. ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT

Prepared by T. Hatch

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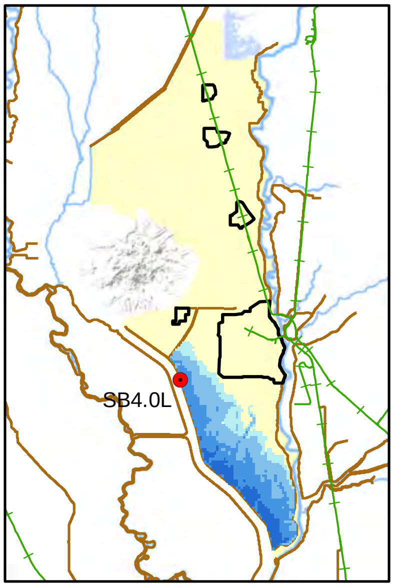
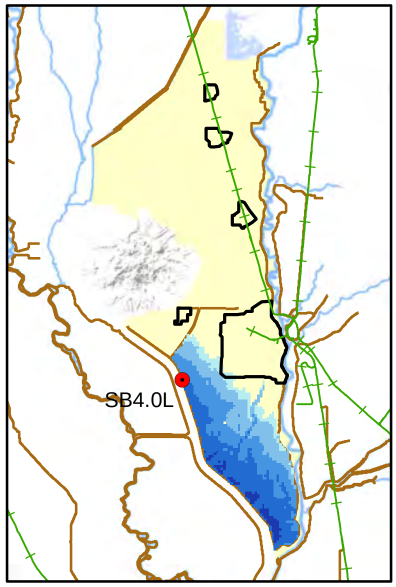
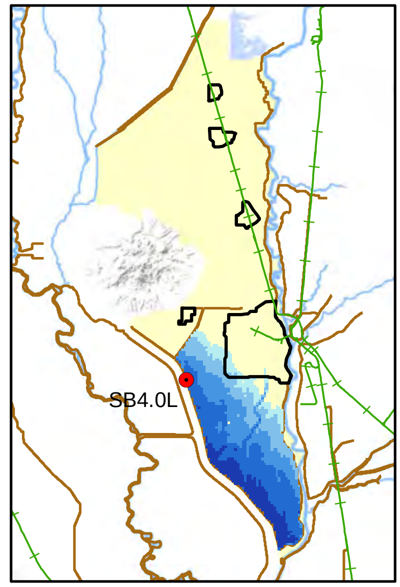


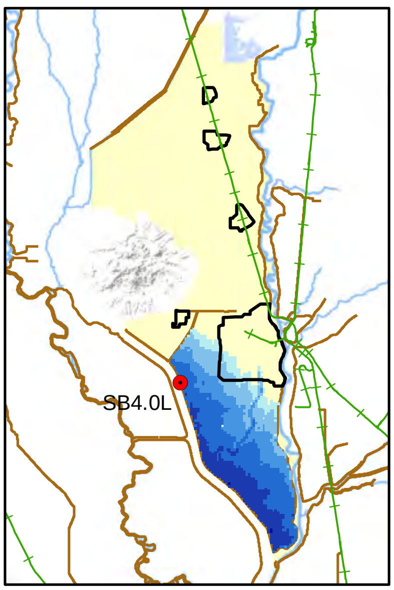
50% (1/2) ACE



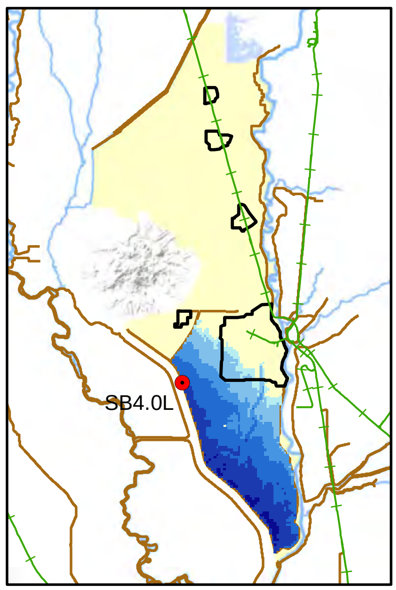
10% (1/10) ACE



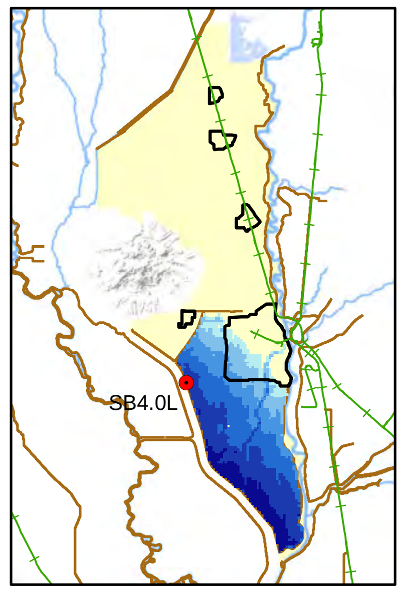
4% (1/25) ACE



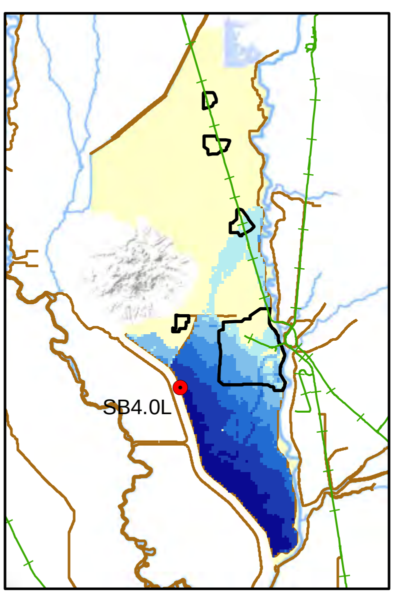
2% (1/50) ACE



1% (1/100) ACE



0.5% (1/200) ACE



0.2% (1/500) ACE

Depth

(ft)

- less than 2
- 2 to 6
- 6 to 10
- 10 to 15
- 15 to 20
- greater than 20

Railroad

Miles
0 10 20

NOTE: MAP DEPICTS OVERTOPPING WITHOUT FAILURE IN REACHES WITHOUT A BREACH

SUTTER BASIN PILOT FEASIBILITY STUDY
SUTTER BASIN, CALIFORNIA

BREACH SIMULATION ALTERNATIVE SB-1 SUTTER BYPASS EAST LEVEE LOCATION SB4.0L

U.S. ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT

Prepared by T. Hatch

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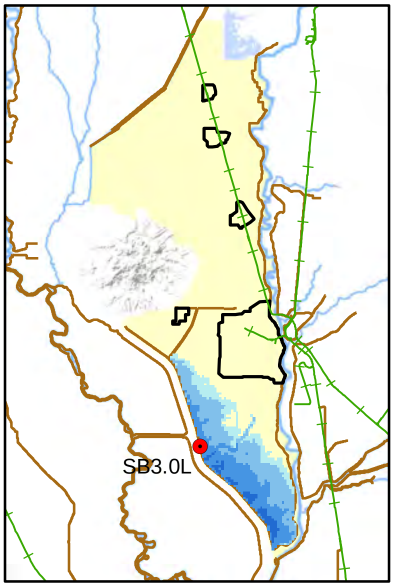
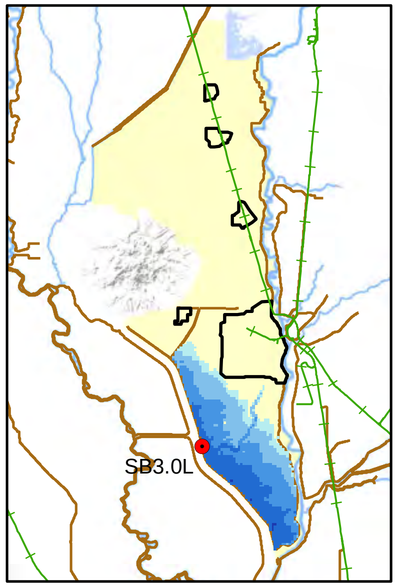
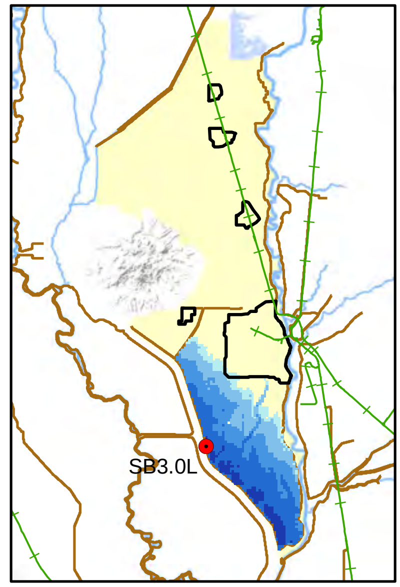


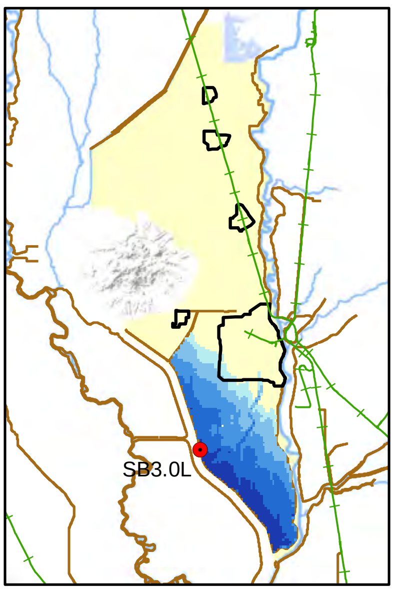
50% (1/2) ACE



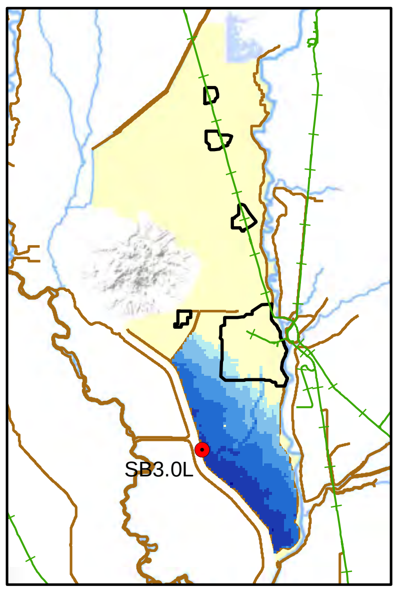
10% (1/10) ACE



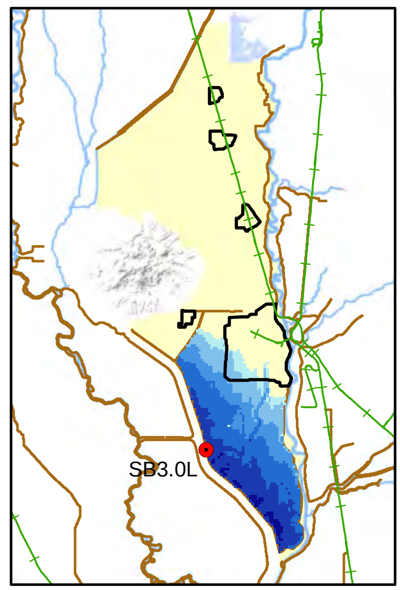
4% (1/25) ACE



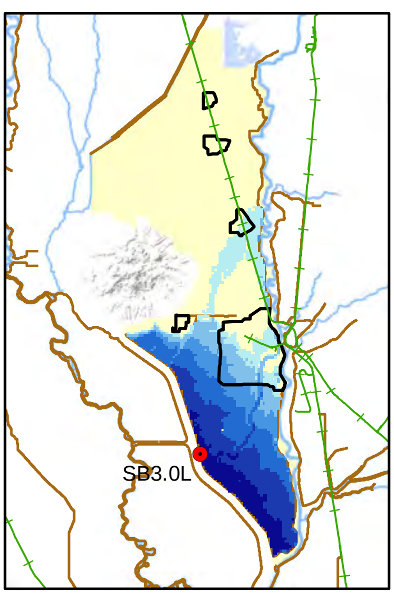
2% (1/50) ACE



1% (1/100) ACE



0.5% (1/200) ACE



0.2% (1/500) ACE

Depth

(ft)

- less than 2
- 2 to 6
- 6 to 10
- 10 to 15
- 15 to 20
- greater than 20

Railroad

NOTE: MAP DEPICTS OVERTOPPING WITHOUT FAILURE IN REACHES WITHOUT A BREACH

Miles
0 10 20

N

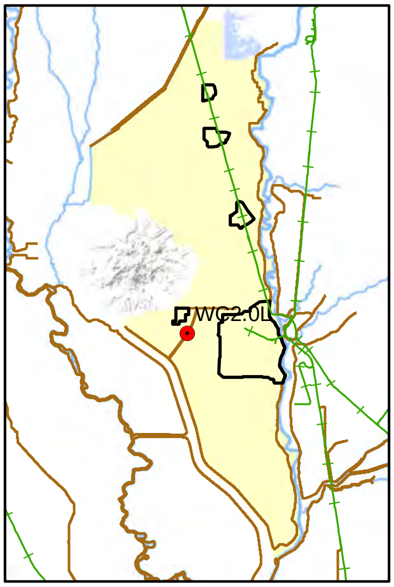
SUTTER BASIN PILOT FEASIBILITY STUDY
SUTTER BASIN, CALIFORNIA

BREACH SIMULATION ALTERNATIVE SB-1 SUTTER BYPASS EAST LEVEE LOCATION SB3.0L

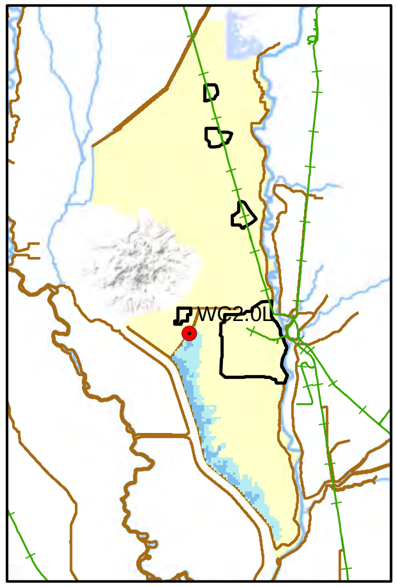
U.S. ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT

Prepared by T. Hatch

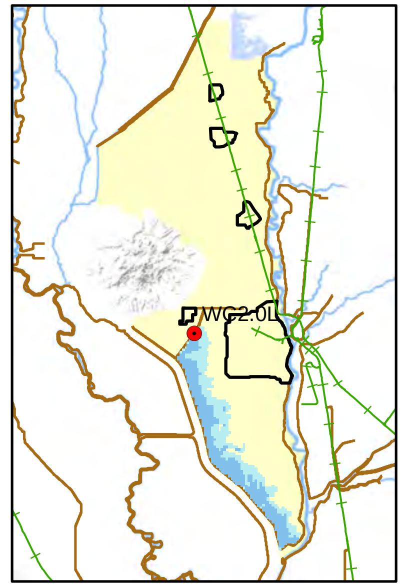
FEB 2013



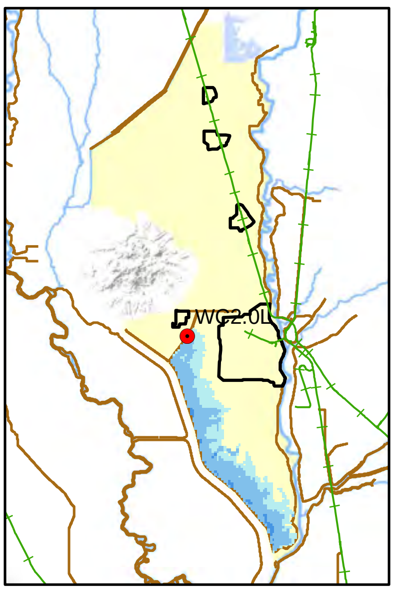
50% (1/2) ACE



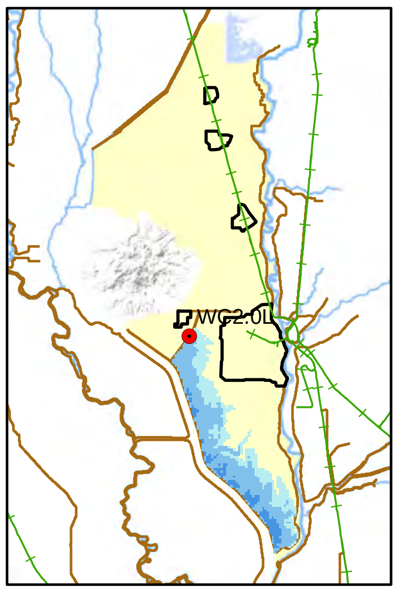
10% (1/10) ACE



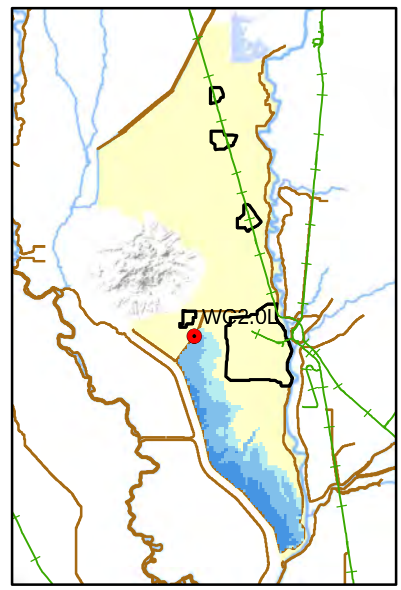
4% (1/25) ACE



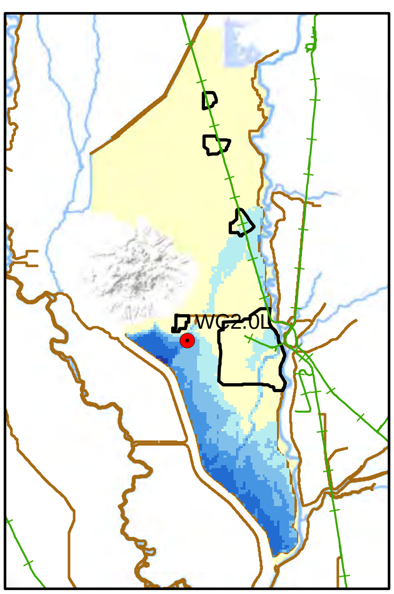
2% (1/50) ACE



1% (1/100) ACE



0.5% (1/200) ACE



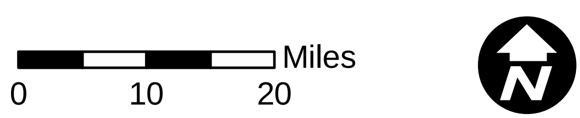
0.2% (1/500) ACE

Depth

(ft)

- less than 2
- 2 to 6
- 6 to 10
- 10 to 15
- 15 to 20
- greater than 20

Railroad



NOTE: MAP DEPICTS OVERTOPPING WITHOUT FAILURE IN REACHES WITHOUT A BREACH

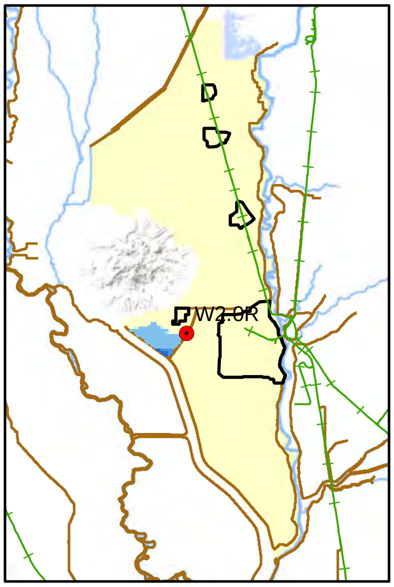
SUTTER BASIN PILOT FEASIBILITY STUDY
SUTTER BASIN, CALIFORNIA

BREACH SIMULATION
ALTERNATIVE SB-1
WADSWORTH CANAL SOUTH LEVEE
LOCATION WC2.0L

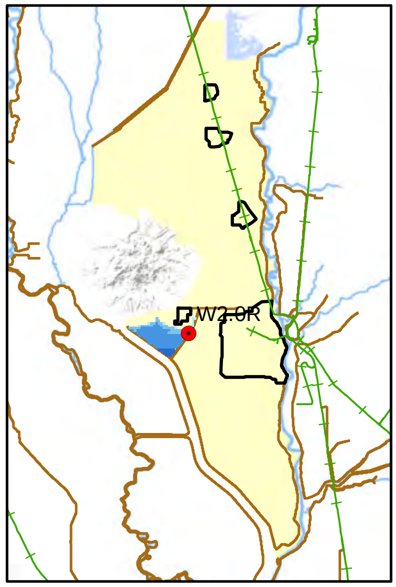
U.S. ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT

Prepared by T. Hatch

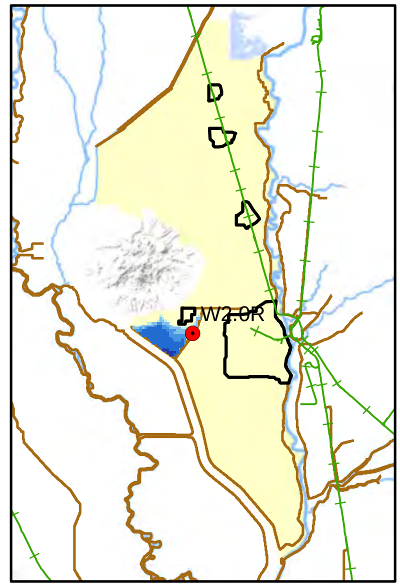
FEB 2013



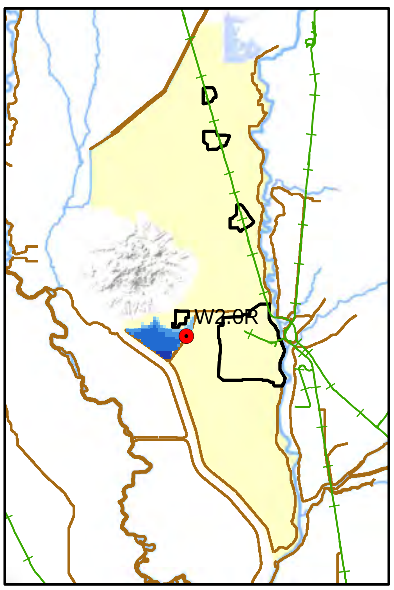
50% (1/2) ACE



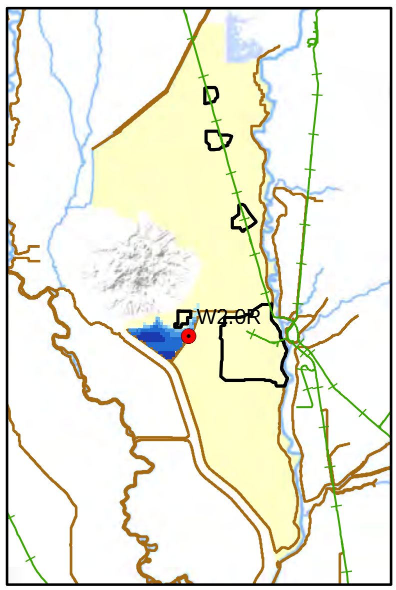
10% (1/10) ACE



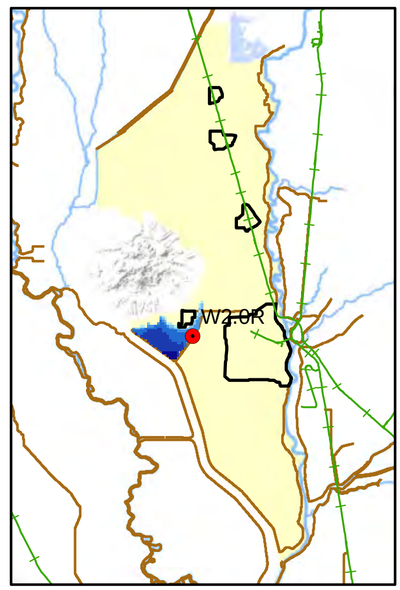
4% (1/25) ACE



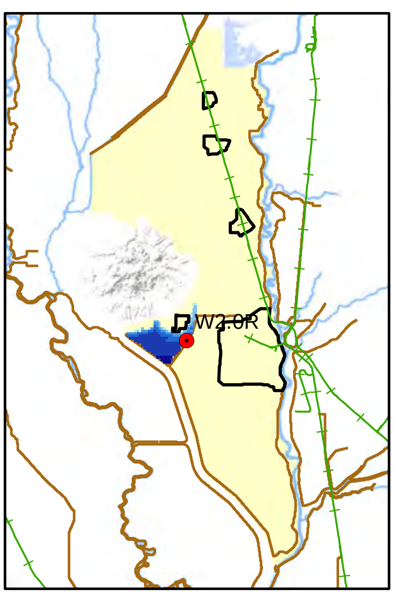
2% (1/50) ACE



1% (1/100) ACE



0.5% (1/200) ACE



0.2% (1/500) ACE

Depth

(ft)

- less than 2
- 2 to 6
- 6 to 10
- 10 to 15
- 15 to 20
- greater than 20

Railroad

Miles
0 10 20

NOTE: MAP DEPICTS OVERTOPPING WITHOUT FAILURE IN REACHES WITHOUT A BREACH

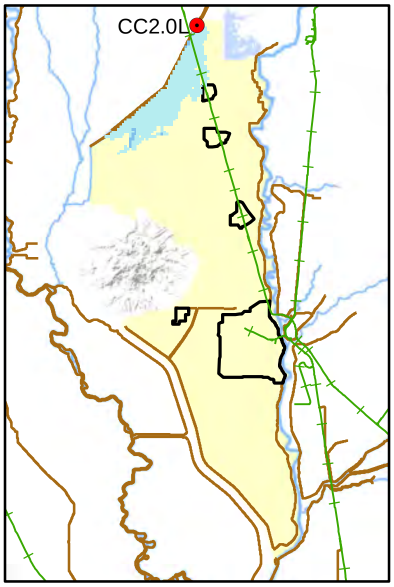
SUTTER BASIN PILOT FEASIBILITY STUDY
SUTTER BASIN, CALIFORNIA

BREACH SIMULATION
ALTERNATIVE SB-1
WADSWORTH CANAL NORTH LEVEE
LOCATION W2.0R

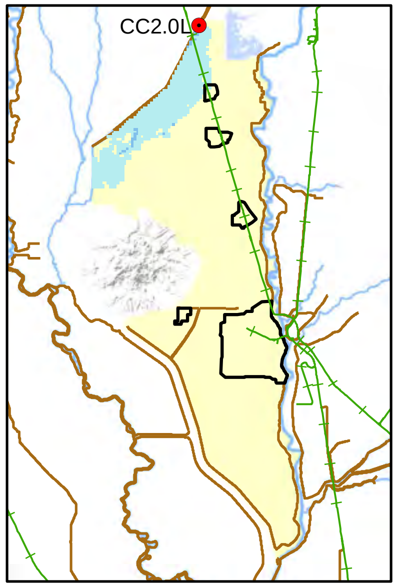
U.S. ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT

Prepared by T. Hatch

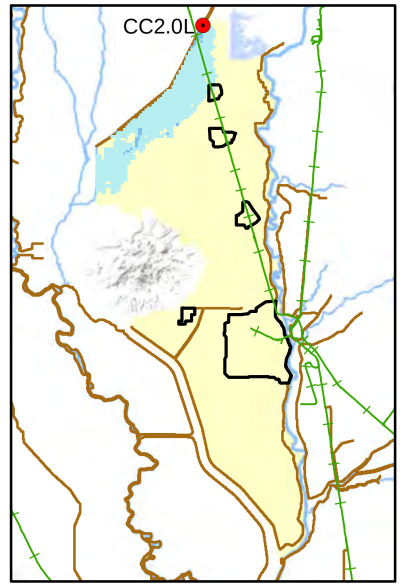
FEB 2013



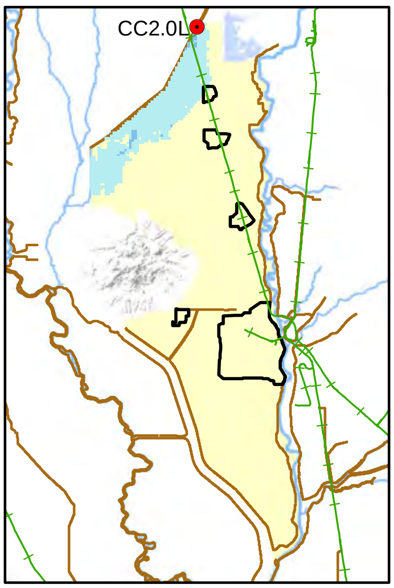
50% (1/2) ACE



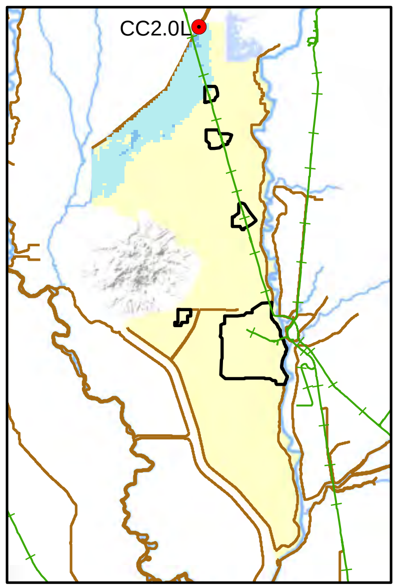
10% (1/10) ACE



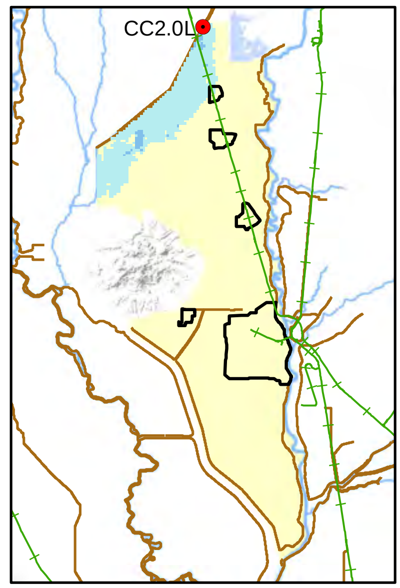
4% (1/25) ACE



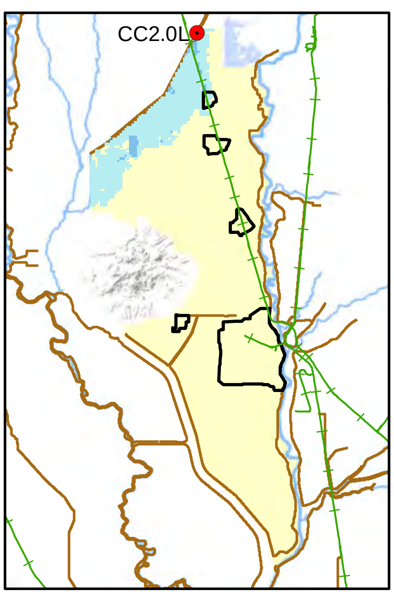
2% (1/50) ACE



1% (1/100) ACE



0.5% (1/200) ACE



0.2% (1/500) ACE

Depth

(ft)

- less than 2
- 2 to 6
- 6 to 10
- 10 to 15
- 15 to 20
- greater than 20

Railroad

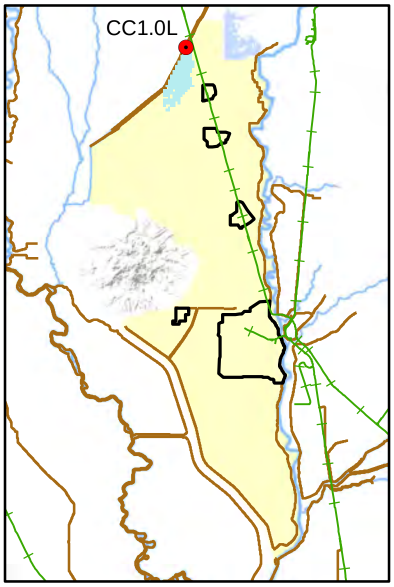
Miles
0 10 20

NOTE: MAP DEPICTS OVERTOPPING WITHOUT FAILURE IN REACHES WITHOUT A BREACH

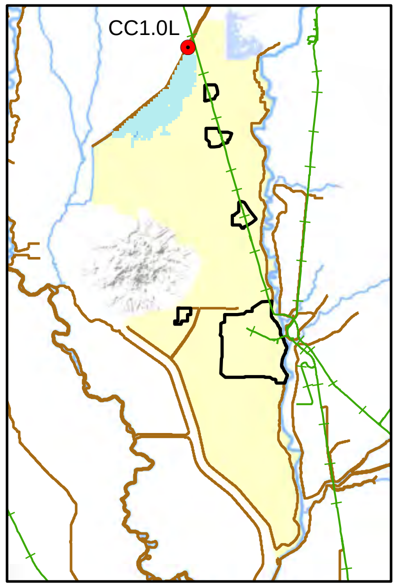
SUTTER BASIN PILOT FEASIBILITY STUDY
SUTTER BASIN, CALIFORNIA

BREACH SIMULATION ALTERNATIVE SB-1 CHEROKEE CANAL SOUTH LEVEE LOCATION CC2.0L

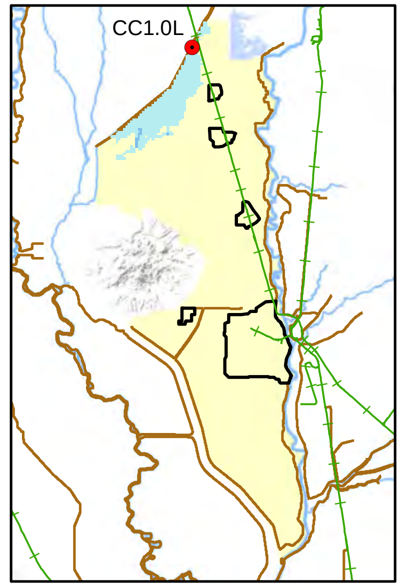
U.S. ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT



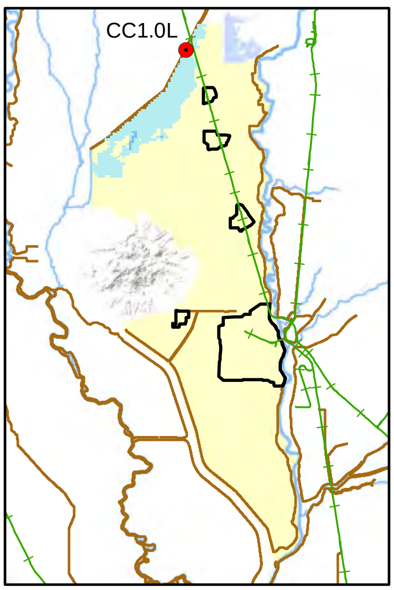
50% (1/2) ACE



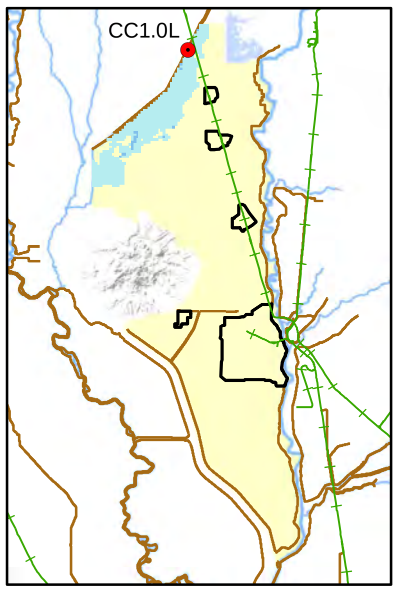
10% (1/10) ACE



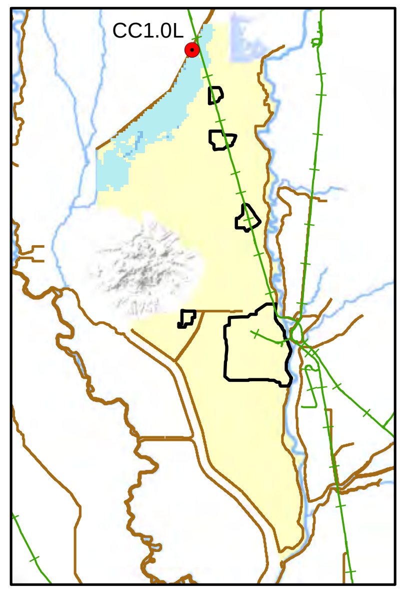
4% (1/25) ACE



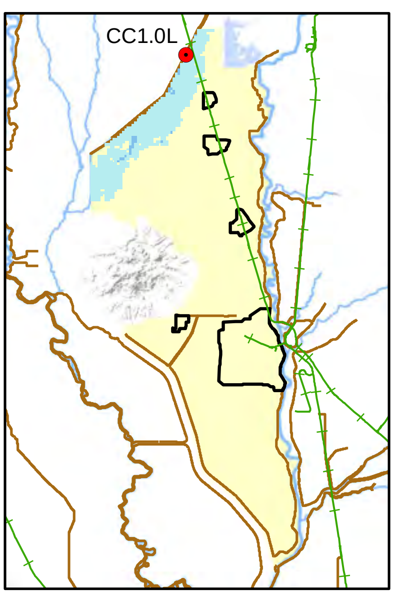
2% (1/50) ACE



1% (1/100) ACE



0.5% (1/200) ACE



0.2% (1/500) ACE

Depth

(ft)

- less than 2
- 2 to 6
- 6 to 10
- 10 to 15
- 15 to 20
- greater than 20

Railroad

NOTE: MAP DEPICTS OVERTOPPING WITHOUT FAILURE IN REACHES WITHOUT A BREACH

Miles
0 10 20

N

SUTTER BASIN PILOT FEASIBILITY STUDY
SUTTER BASIN, CALIFORNIA

BREACH SIMULATION
ALTERNATIVE SB-1
CHEROKEE CANAL SOUTH LEVEE
LOCATION CC1.0L

U.S. ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT

Prepared by T. Hatch

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NOT MODELED

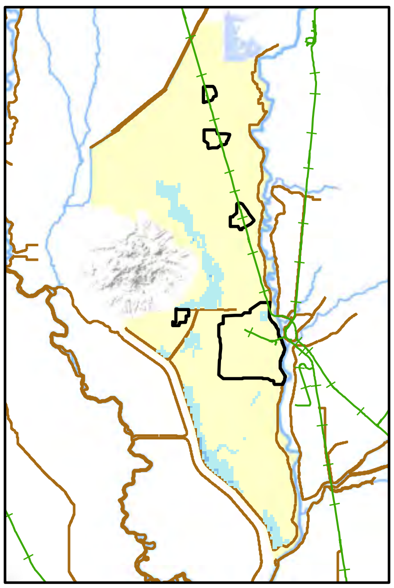
50% (1/2) ACE

NOT MODELED

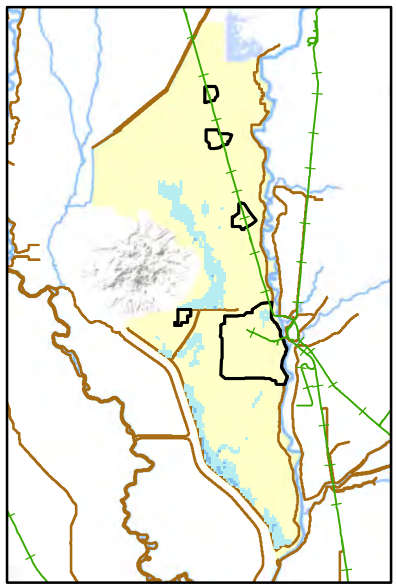
10% (1/10) ACE

NOT MODELED

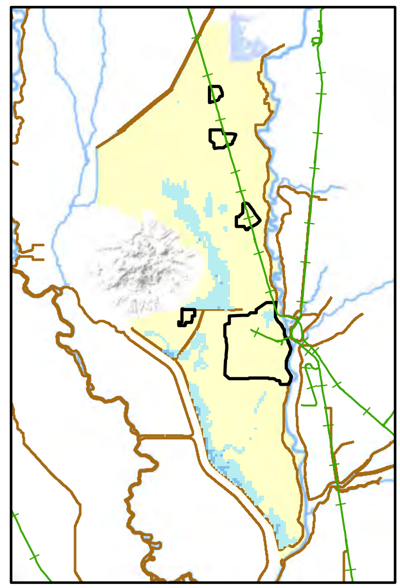
4% (1/25) ACE



2% (1/50) ACE



1% (1/100) ACE



0.5% (1/200) ACE

NOT MODELED

0.2% (1/500) ACE

Depth

(ft)

- less than 2
- 2 to 6
- 6 to 10
- 10 to 15
- 15 to 20
- greater than 20

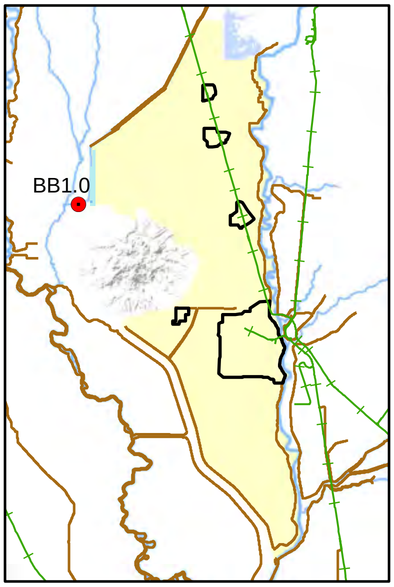
Railroad

Miles
0 10 20

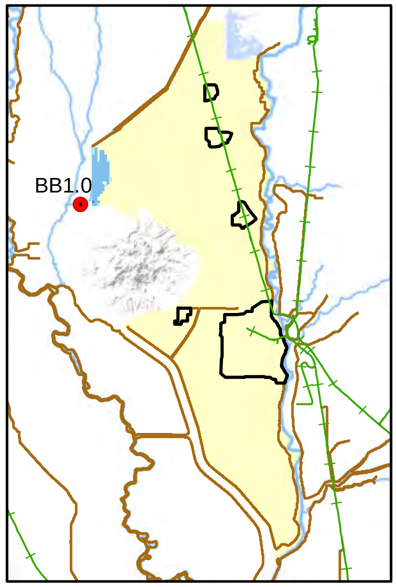
SUTTER BASIN PILOT FEASIBILITY STUDY
SUTTER BASIN, CALIFORNIA

INTERIOR DRAINAGE ALTERNATIVE SB-1

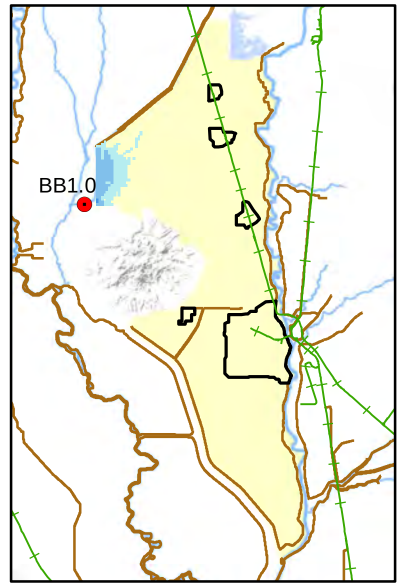
U.S. ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT



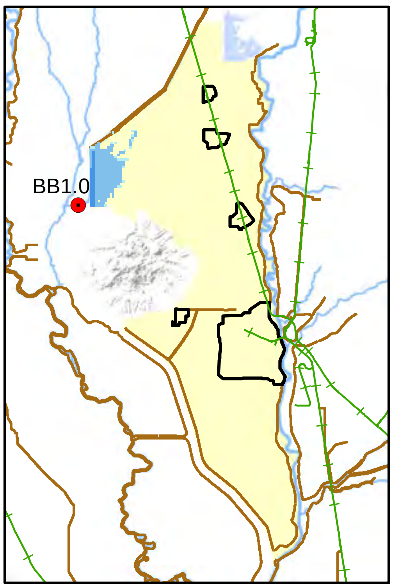
50% (1/2) ACE



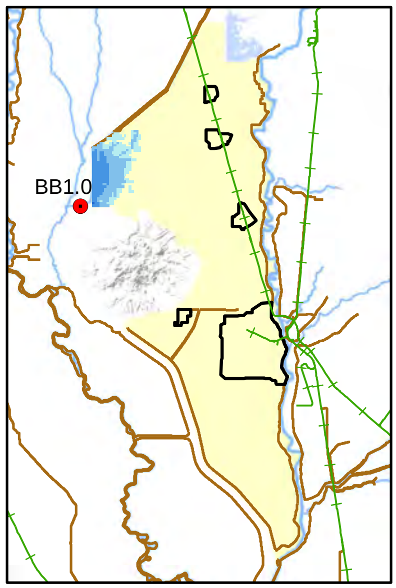
10% (1/10) ACE



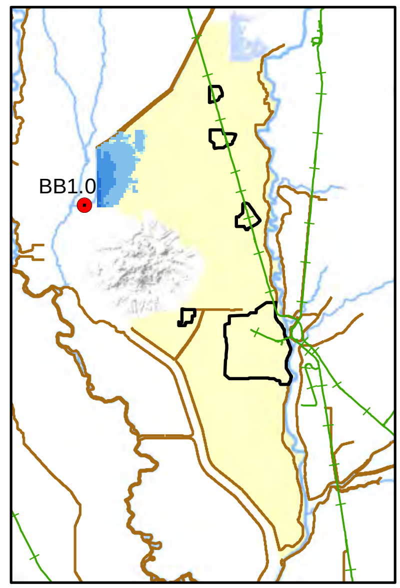
4% (1/25) ACE



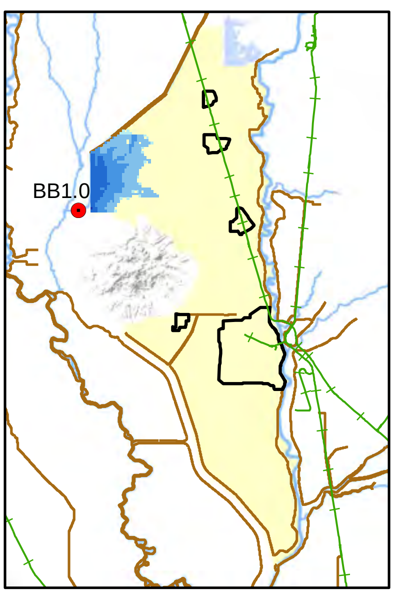
2% (1/50) ACE



1% (1/100) ACE



0.5% (1/200) ACE



0.2% (1/500) ACE

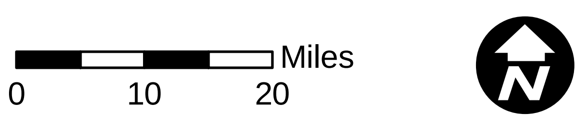
Depth

(ft)

- less than 2
- 2 to 6
- 6 to 10
- 10 to 15
- 15 to 20
- greater than 20

Railroad

NOTE: MAP DEPICTS OVERTOPPING WITHOUT FAILURE IN REACHES WITHOUT A BREACH



SUTTER BASIN PILOT FEASIBILITY STUDY
SUTTER BASIN, CALIFORNIA

ALTERNATIVE SB-1
BUTTE BASIN
LOCATION BB1.0

U.S. ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT

Prepared by T. Hatch

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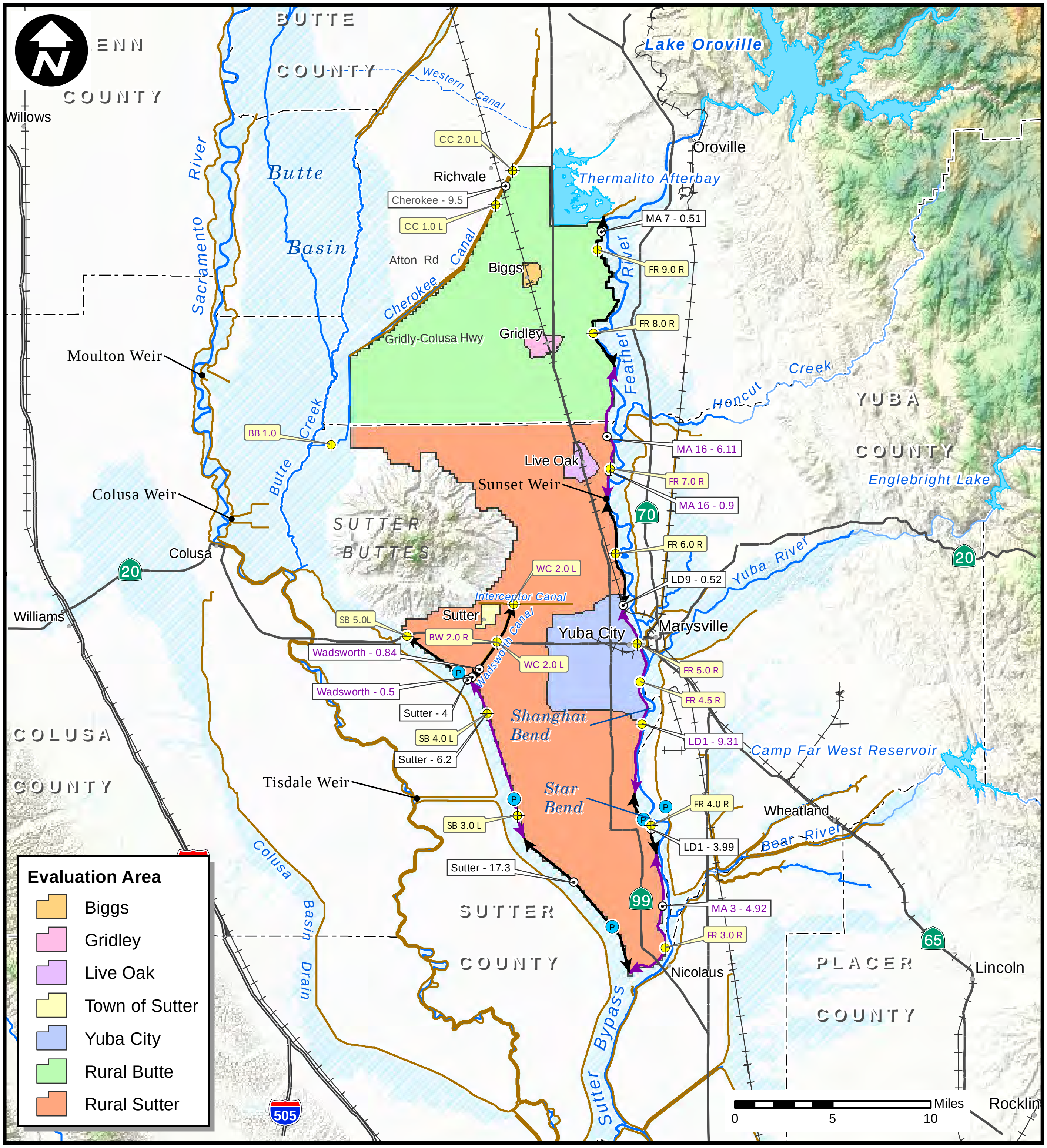


Legend

- Geotechnical Levee Reach
- Federal Levee
- Breach Simulation Site
- Geotechnical Index Point
- Pump Station
- City or Town
- Designated Floodways
- Lake or Reservoir
- River or Stream
- Railroad
- County Boundary

SUTTER BASIN PILOT FEASIBILITY STUDY
SUTTER BASIN, CALIFORNIA

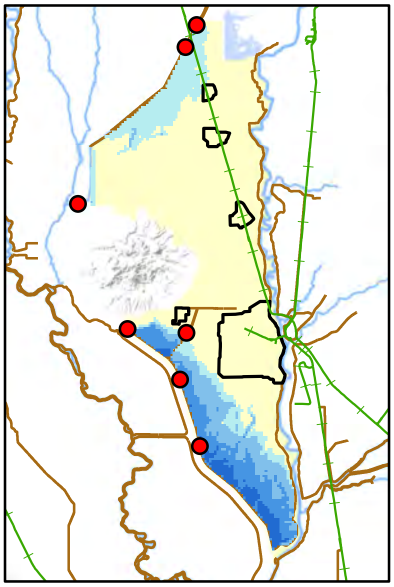
INDEX POINTS AND ECONOMIC IMPACT AREAS

U.S. ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT

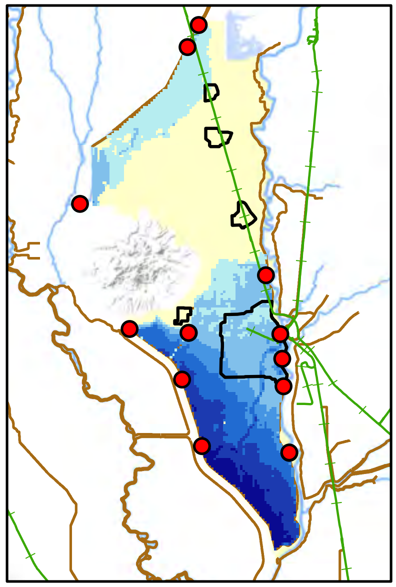
Prepared by Jim Mars

FEB 2013

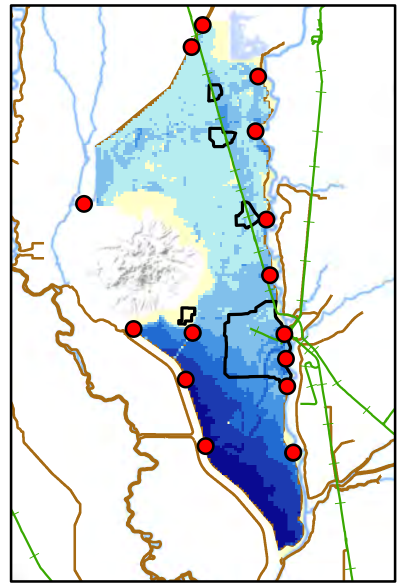
PLATE 48



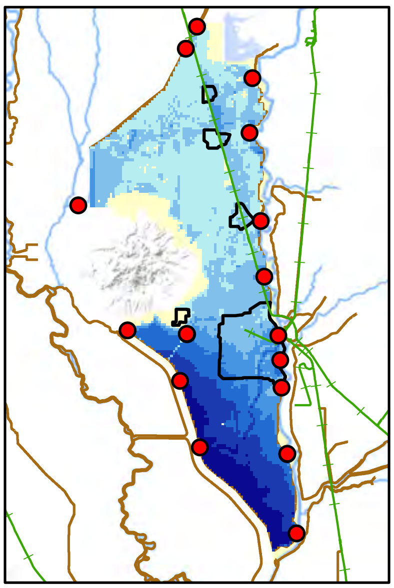
50% (1/2) ACE



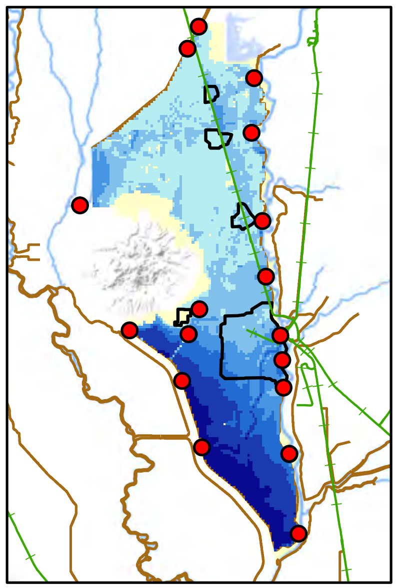
10% (1/10) ACE



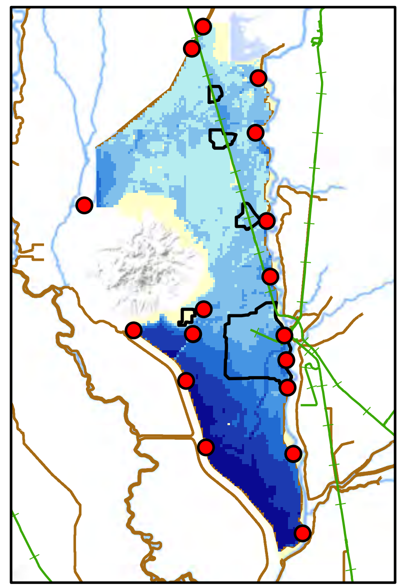
4% (1/25) ACE



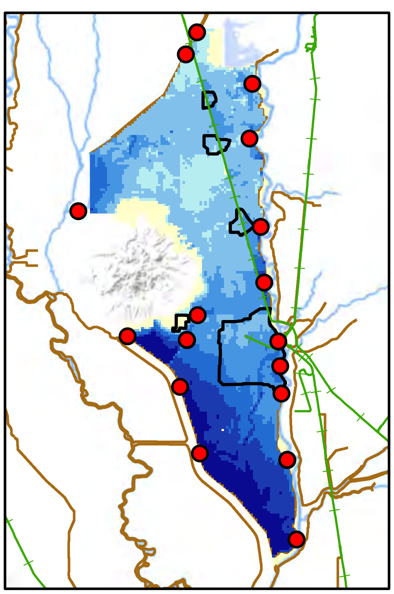
2% (1/50) ACE



1% (1/100) ACE



0.5% (1/200) ACE



0.2% (1/500) ACE

Depth

(ft)

- less than 2
- 2 to 6
- 6 to 10
- 10 to 15
- 15 to 20
- greater than 20

Railroad

Levee Fails R&U Criteria

NOTE: Breach simulation shown if levee does not pass assurance criteria.1) Assurance less than 90% the levee does not pass criteria 2) For assurance between 90 and 95% levee must have minimum of 3 feet of freeboard to pass criteria. 3) For assurance greater than 95% levee must have minimum of 2 feet of freeboard to pass criteria

Miles

0 10 20

N

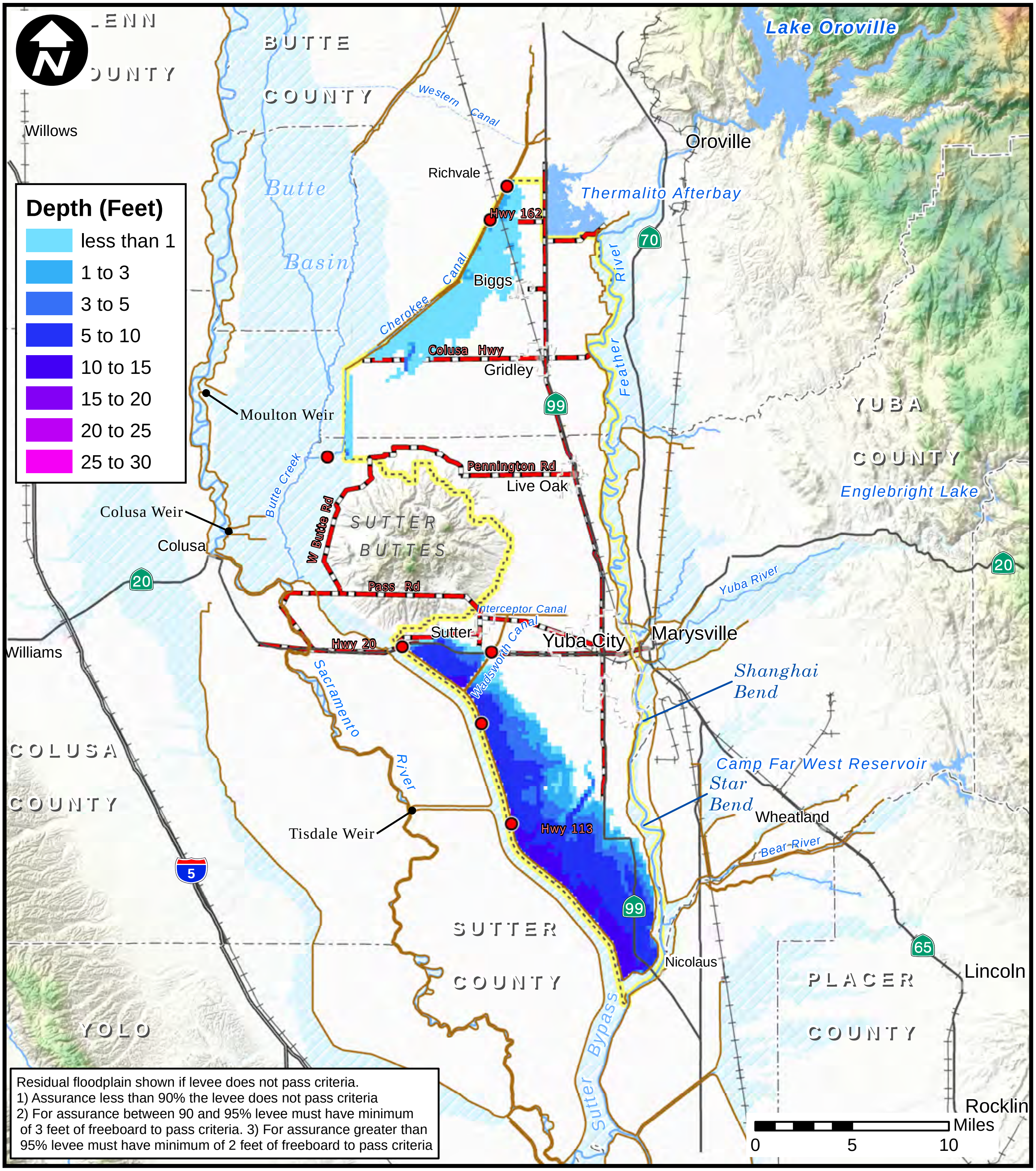
SUTTER BASIN PILOT FEASIBILITY STUDY
SUTTER BASIN, CALIFORNIA

COMPOSITE FLOODPLAINS ALTERNATIVE SB-1 WITHOUT PROJECT CONDITIONS

U.S. ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT

Prepared by T. Hatch

FEB 2013



Legend

Federal Levee	Breach Simulation Point
River or Stream	Evacuation Routes
Lake or Reservoir	Highway
Designated Floodways	Railroad
Study Area Extent	County Boundary
	City Limit

SUTTER BASIN PILOT FEASIBILITY STUDY
SUTTER BASIN, CALIFORNIA

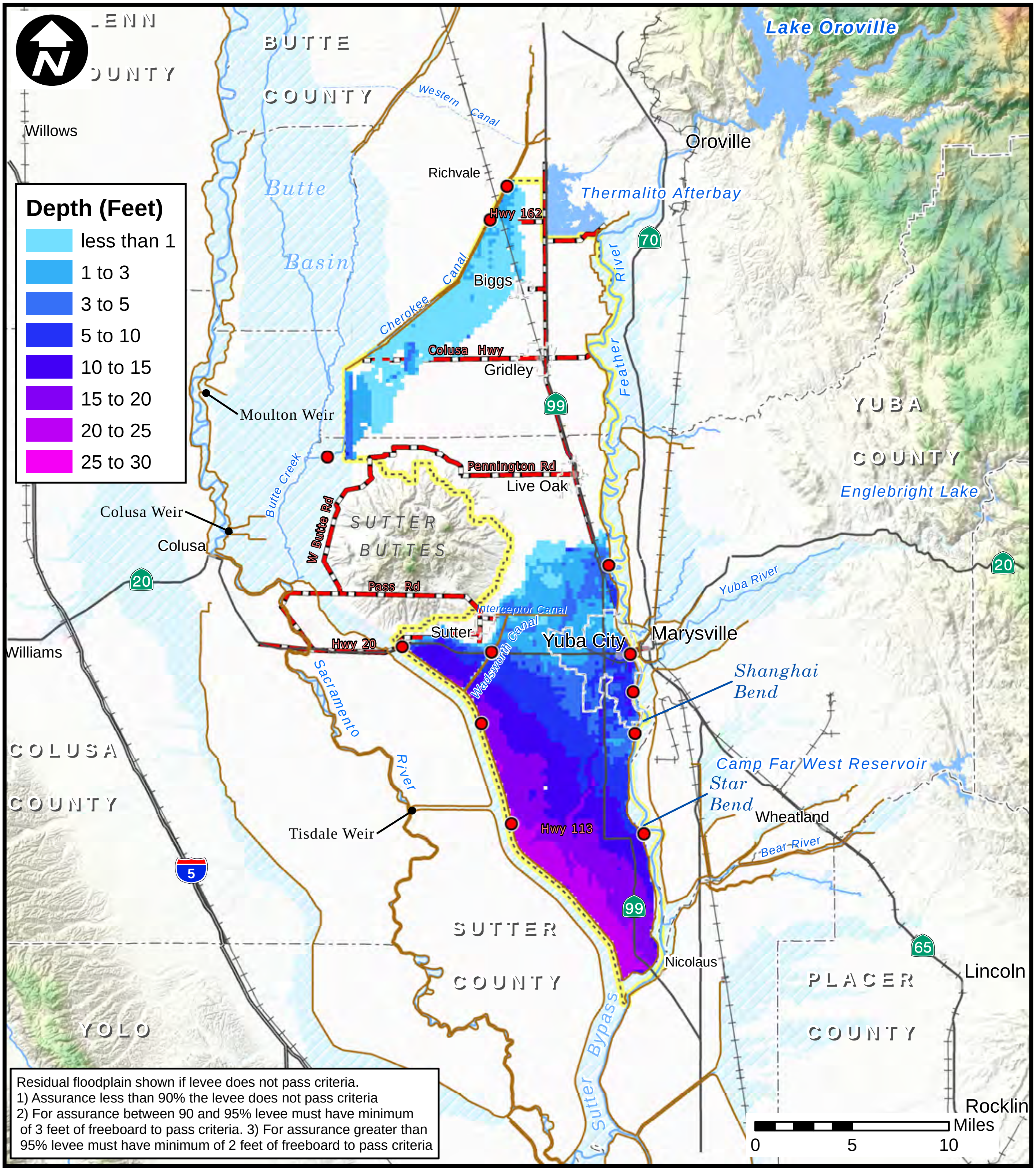
50% (1/2) ACE FLOODPLAIN ALTERNATIVE SB-1 WITHOUT PROJECT CONDITIONS

U.S. ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT

Prepared by Jim Mars

FEB 2013

PLATE 50



Legend

- Federal Levee
- River or Stream
- Lake or Reservoir
- Designated Floodways
- Study Area Extent
- Breach Simulation Point
- Evacuation Routes
- Highway
- Railroad
- County Boundary
- City Limit

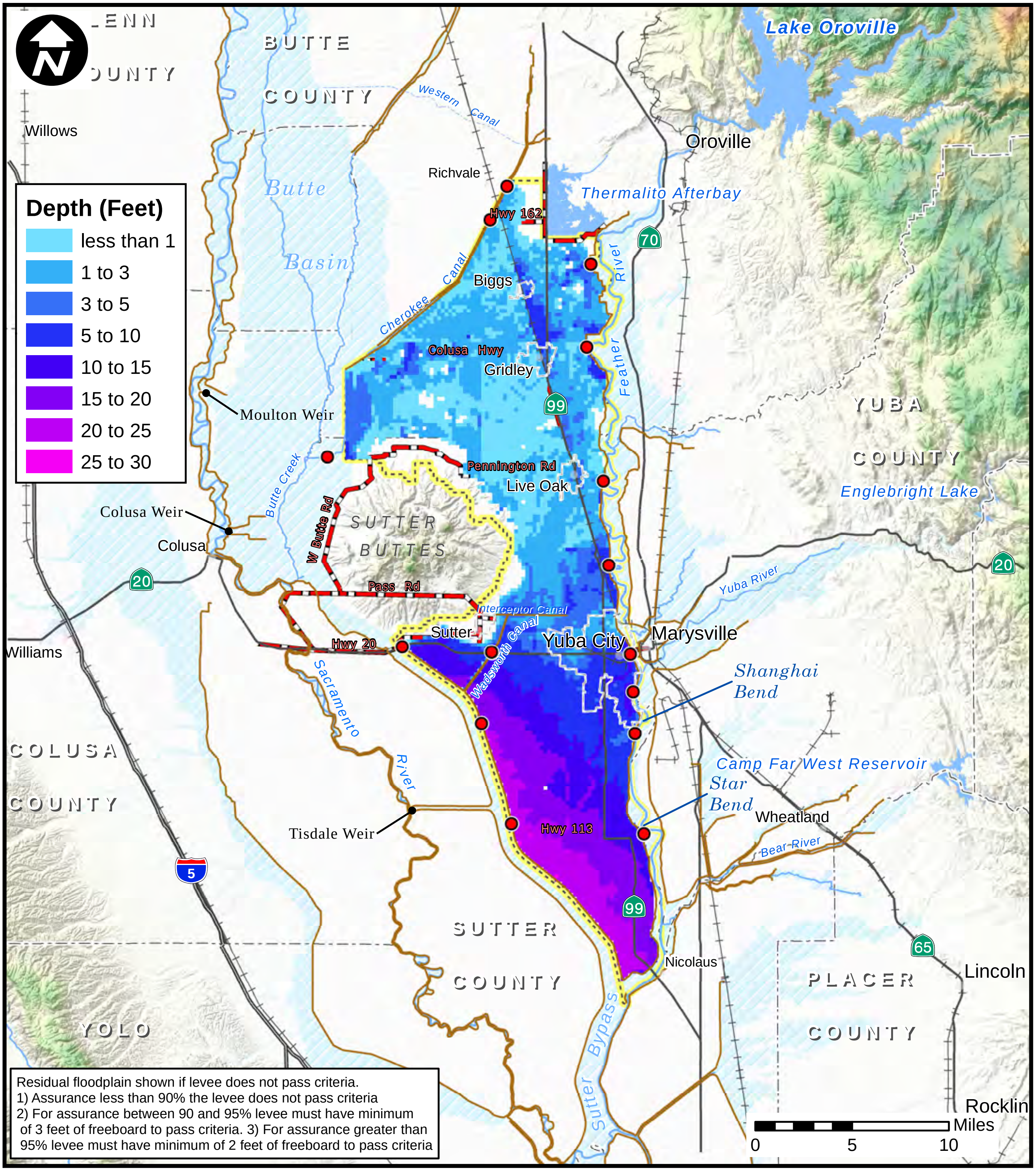
SUTTER BASIN PILOT FEASIBILITY STUDY
SUTTER BASIN, CALIFORNIA

10% (1/10) ACE FLOODPLAIN ALTERNATIVE SB-1 WITHOUT PROJECT CONDITIONS

U.S. ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT

Prepared by Jim Mars

FEB 2013



Legend

- Federal Levee
- River or Stream
- Lake or Reservoir
- Designated Floodways
- Study Area Extent
- Breach Simulation Point
- Evacuation Routes
- Highway
- Railroad
- County Boundary
- City Limit

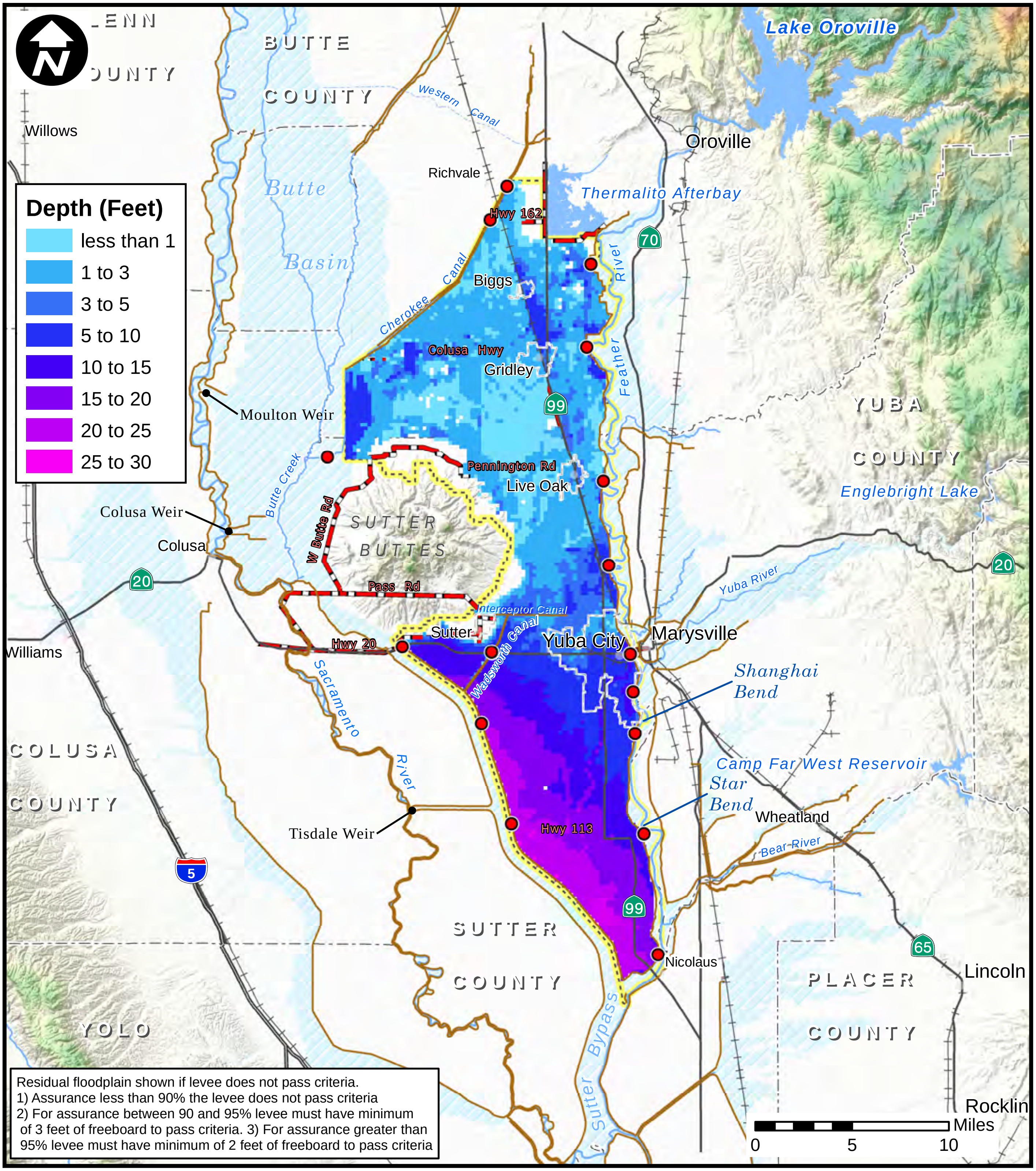
SUTTER BASIN PILOT FEASIBILITY STUDY
SUTTER BASIN, CALIFORNIA

4% (1/25) ACE FLOODPLAIN ALTERNATIVE SB-1 WITHOUT PROJECT CONDITIONS

U.S. ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT

Prepared by Jim Mars

FEB 2013



Legend

- Federal Levee
- River or Stream
- Lake or Reservoir
- Designated Floodways
- Study Area Extent
- Breach Simulation Point
- Evacuation Routes
- Highway
- Railroad
- County Boundary
- City Limit

SUTTER BASIN PILOT FEASIBILITY STUDY
SUTTER BASIN, CALIFORNIA

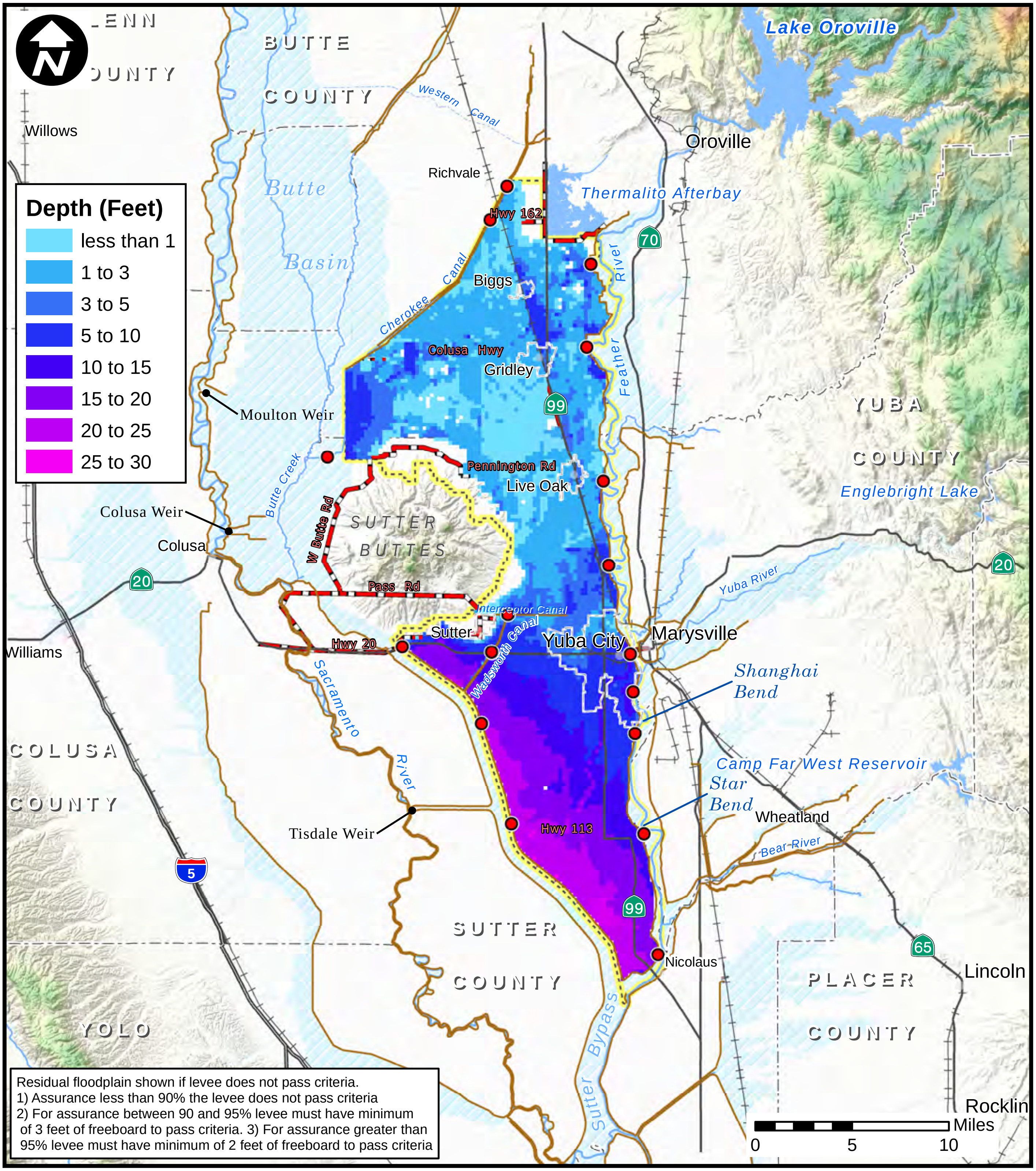
2% (1/50) ACE FLOODPLAIN
ALTERNATIVE SB-1
WITHOUT PROJECT CONDITIONS

U.S. ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT

Prepared by Jim Mars

FEB 2013

PLATE 53



Legend

Federal Levee	Breach Simulation Point
River or Stream	Evacuation Routes
Lake or Reservoir	Highway
Designated Floodways	Railroad
Study Area Extent	County Boundary
	City Limit

SUTTER BASIN PILOT FEASIBILITY STUDY
SUTTER BASIN, CALIFORNIA

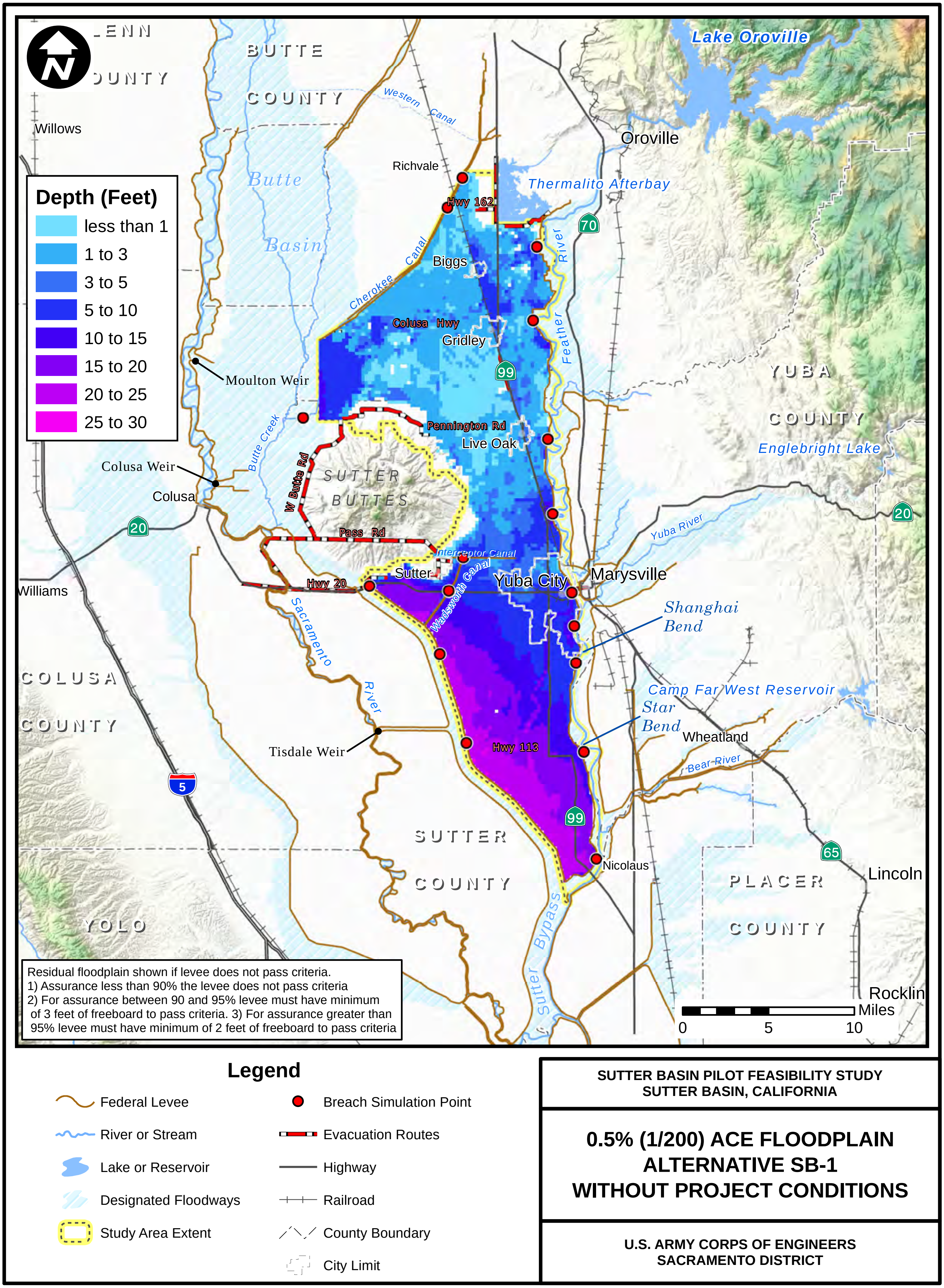
1% (1/100) ACE FLOODPLAIN ALTERNATIVE SB-1 WITHOUT PROJECT CONDITIONS

U.S. ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT

Prepared by Jim Mars

FEB 2013

PLATE 54



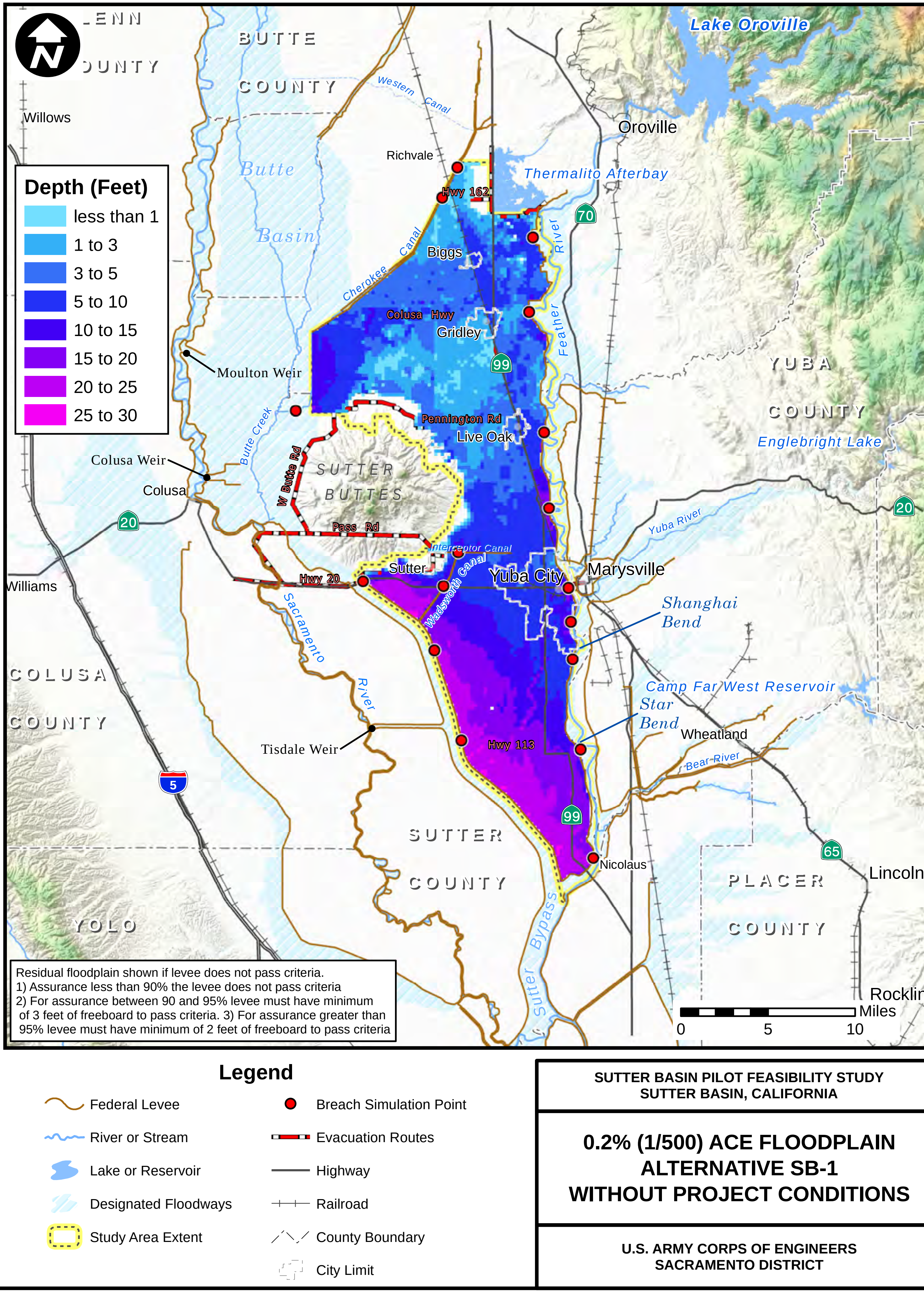
SUTTER BASIN PILOT FEASIBILITY STUDY
SUTTER BASIN, CALIFORNIA

0.5% (1/200) ACE FLOODPLAIN ALTERNATIVE SB-1 WITHOUT PROJECT CONDITIONS

U.S. ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT

Prepared by Jim Mars

FEB 2013



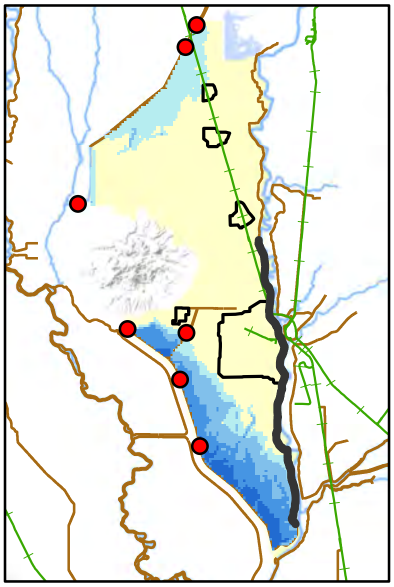
SUTTER BASIN PILOT FEASIBILITY STUDY
SUTTER BASIN, CALIFORNIA

0.2% (1/500) ACE FLOODPLAIN ALTERNATIVE SB-1 WITHOUT PROJECT CONDITIONS

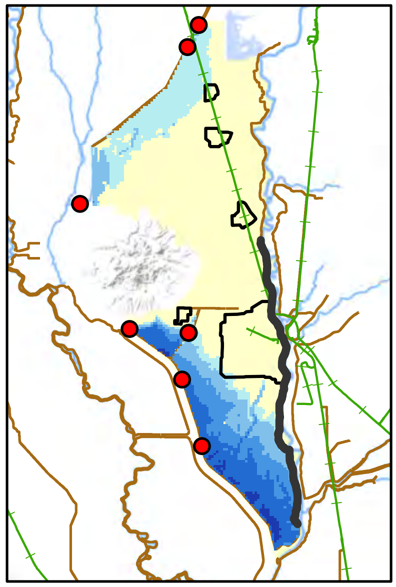
U.S. ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT

Prepared by Jim Mars

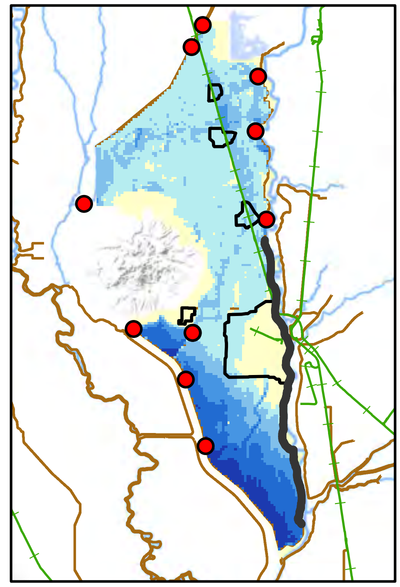
FEB 2013



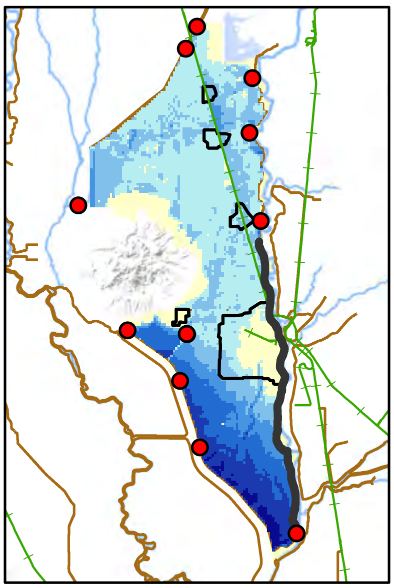
50% (1/2) ACE



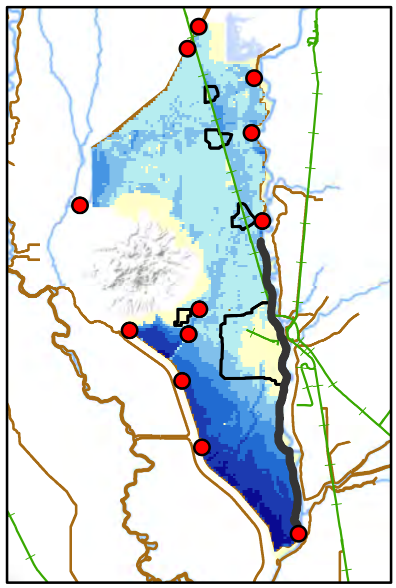
10% (1/10) ACE



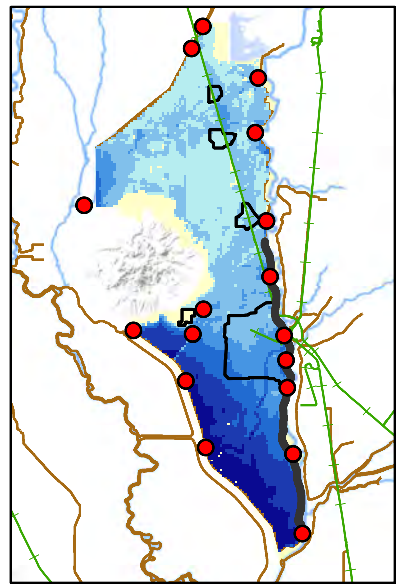
4% (1/25) ACE



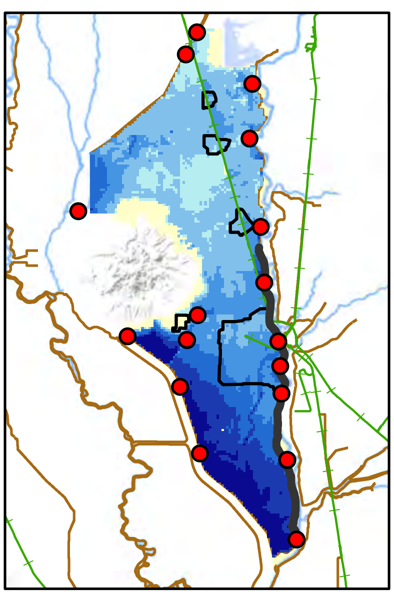
2% (1/50) ACE



1% (1/100) ACE



0.5% (1/200) ACE



0.2% (1/500) ACE

Depth

(ft)

- less than 2
- 2 to 6
- 6 to 10
- 10 to 15
- 15 to 20
- greater than 20

Railroad

Alternative

Levee Fails R&U Criteria

NOTE: Breach simulation shown if levee does not pass assurance criteria.1) Assurance less than 90% the levee does not pass criteria 2) For assurance between 90 and 95% levee must have minimum of 3 feet of freeboard to pass criteria. 3) For assurance greater than 95% levee must have minimum of 2 feet of freeboard to pass criteria

0 10 20 Miles

N

SUTTER BASIN PILOT FEASIBILITY STUDY
SUTTER BASIN, CALIFORNIA

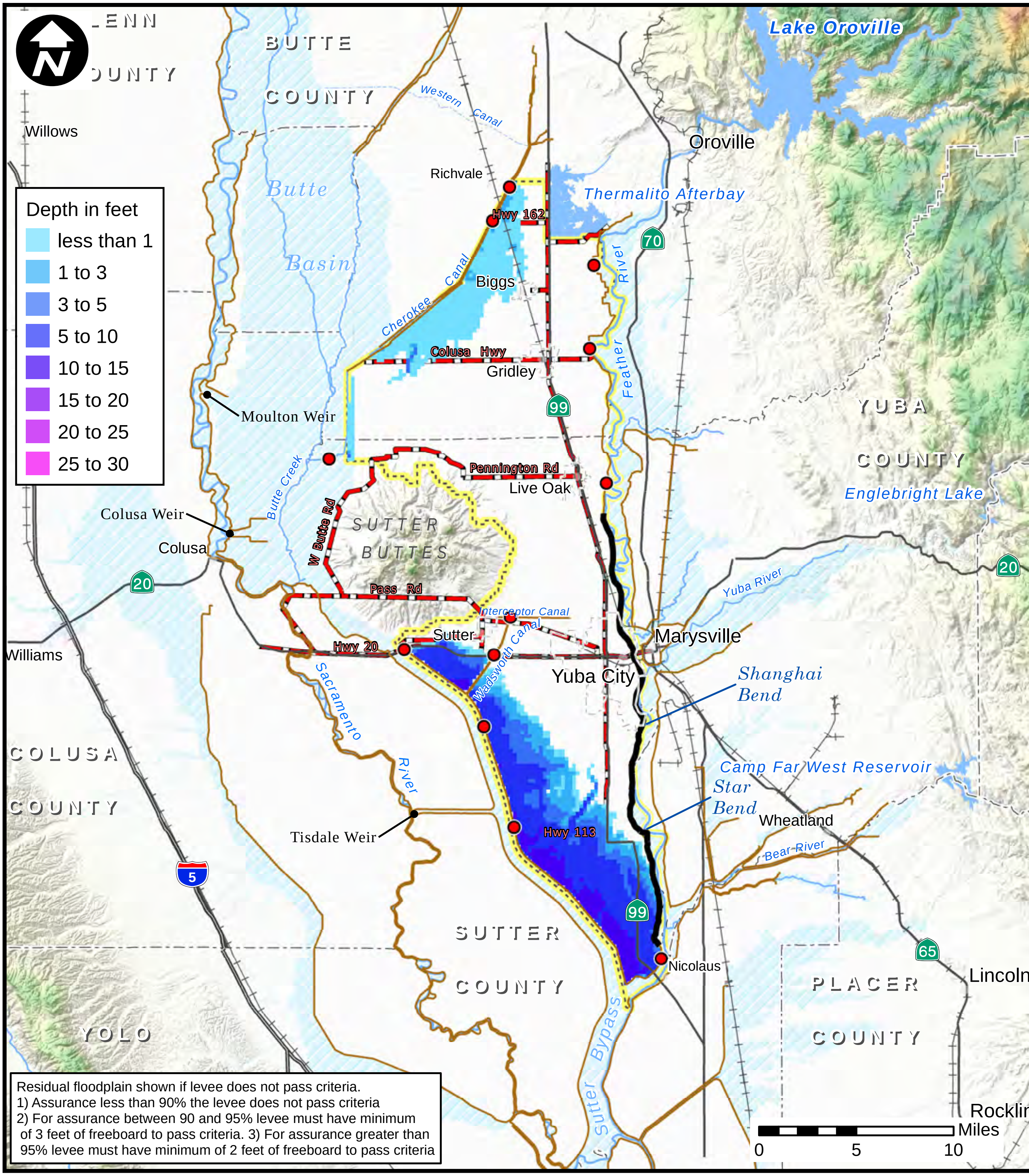
R&U ASSURANCE FLOODPLAINS ALTERNATIVE SB-7 FIX-IN-PLACE SUNSET WEIR TO LAUREL AVE

U.S. ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT

Prepared by T. Hatch

FEB 2013

PLATE 57



Legend

- Federal Levee
- Alternative SB-7
- River or Stream
- Lake or Reservoir
- Designated Floodways
- Study Area Extent
- Levee Fails Criteria
- Evacuation Routes
- Highway
- Railroad
- County Boundary
- City Limit

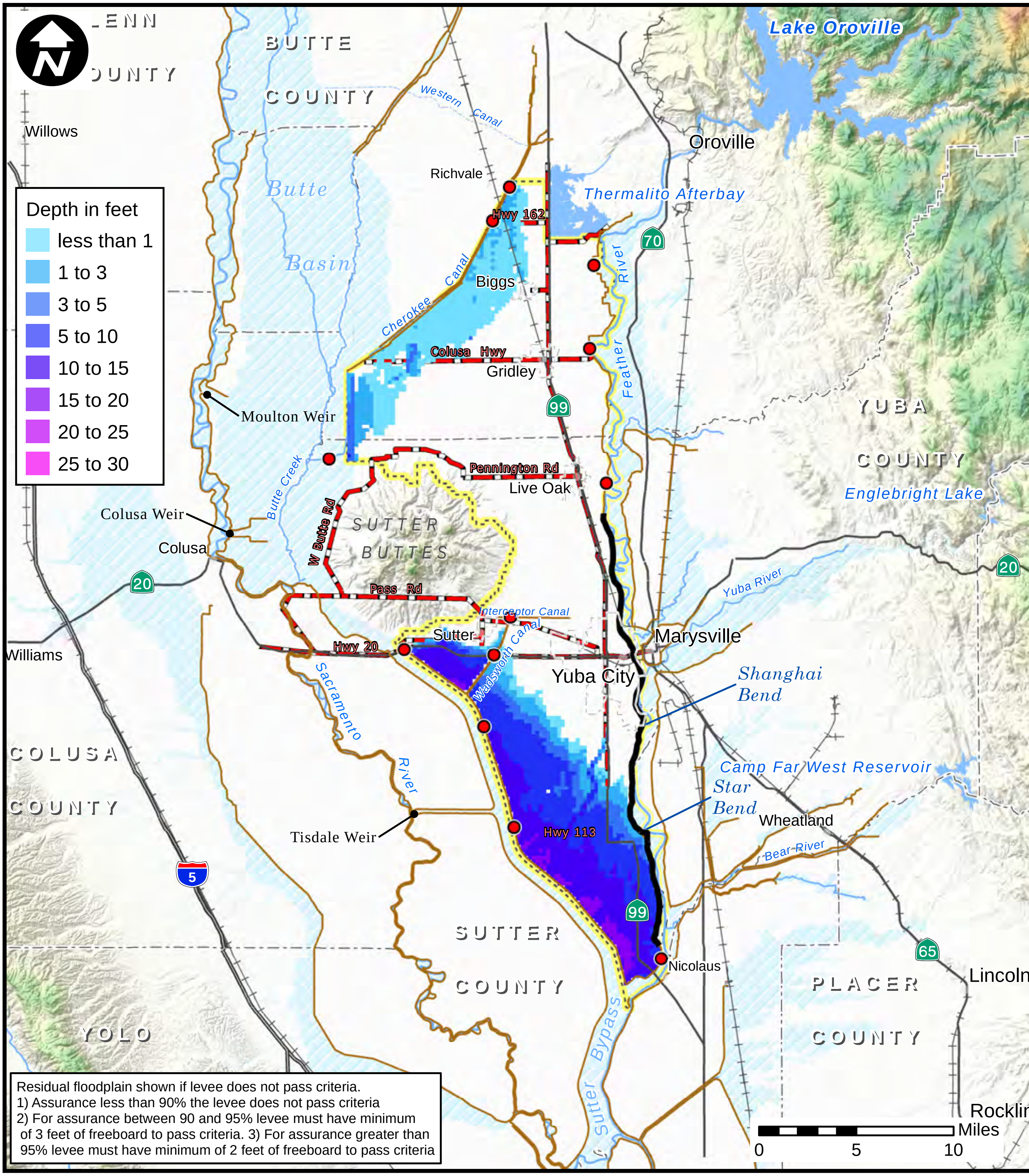
SUTTER BASIN PILOT FEASIBILITY STUDY
SUTTER BASIN, CALIFORNIA

50% (1/2) ACE FLOODPLAIN ALTERNATIVE SB-7 FIX IN PLACE FEATHER RIVER, SUNSET WEIR TO LAUREL AVE

U.S. ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT

Prepared by Jim Mars

FEB 2013



Legend

- Federal Levee
- Alternative SB-7
- River or Stream
- Lake or Reservoir
- Designated Floodways
- Study Area Extent
- Levee Fails Criteria
- Evacuation Routes
- Highway
- Railroad
- County Boundary
- City Limit

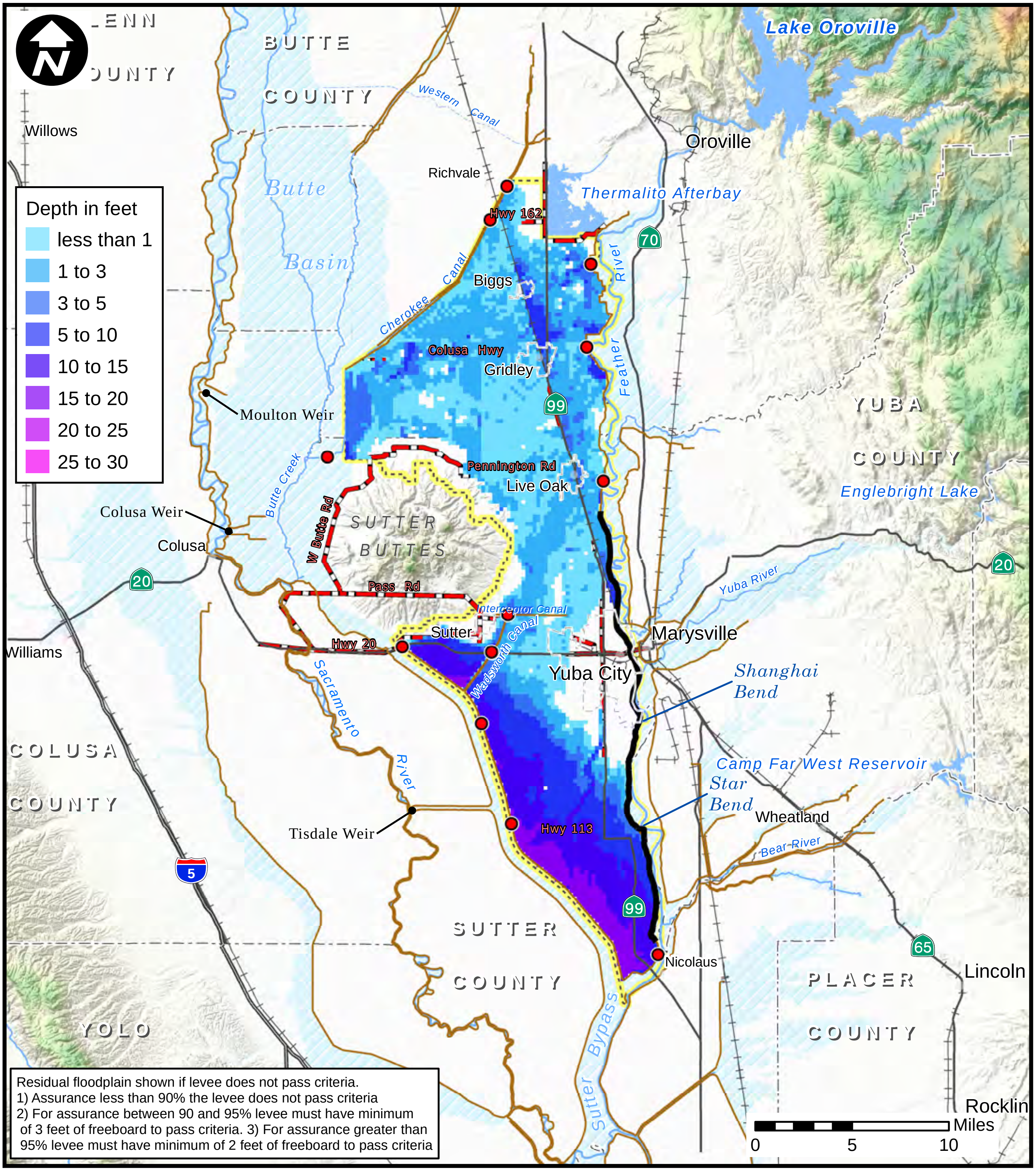
SUTTER BASIN PILOT FEASIBILITY STUDY
SUTTER BASIN, CALIFORNIA

10% (1/10) ACE FLOODPLAIN ALTERNATIVE SB-7 FIX IN PLACE FEATHER RIVER, SUNSET WEIR TO LAUREL AVE

U.S. ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT

Prepared by Jim Mars

FEB 2013



Legend

Federal Levee
Alternative SB-7
River or Stream
Lake or Reservoir
Designated Floodways
Study Area Extent
Levee Fails Criteria
Evacuation Routes
Highway
Railroad
County Boundary
City Limit

SUTTER BASIN PILOT FEASIBILITY STUDY
SUTTER BASIN, CALIFORNIA

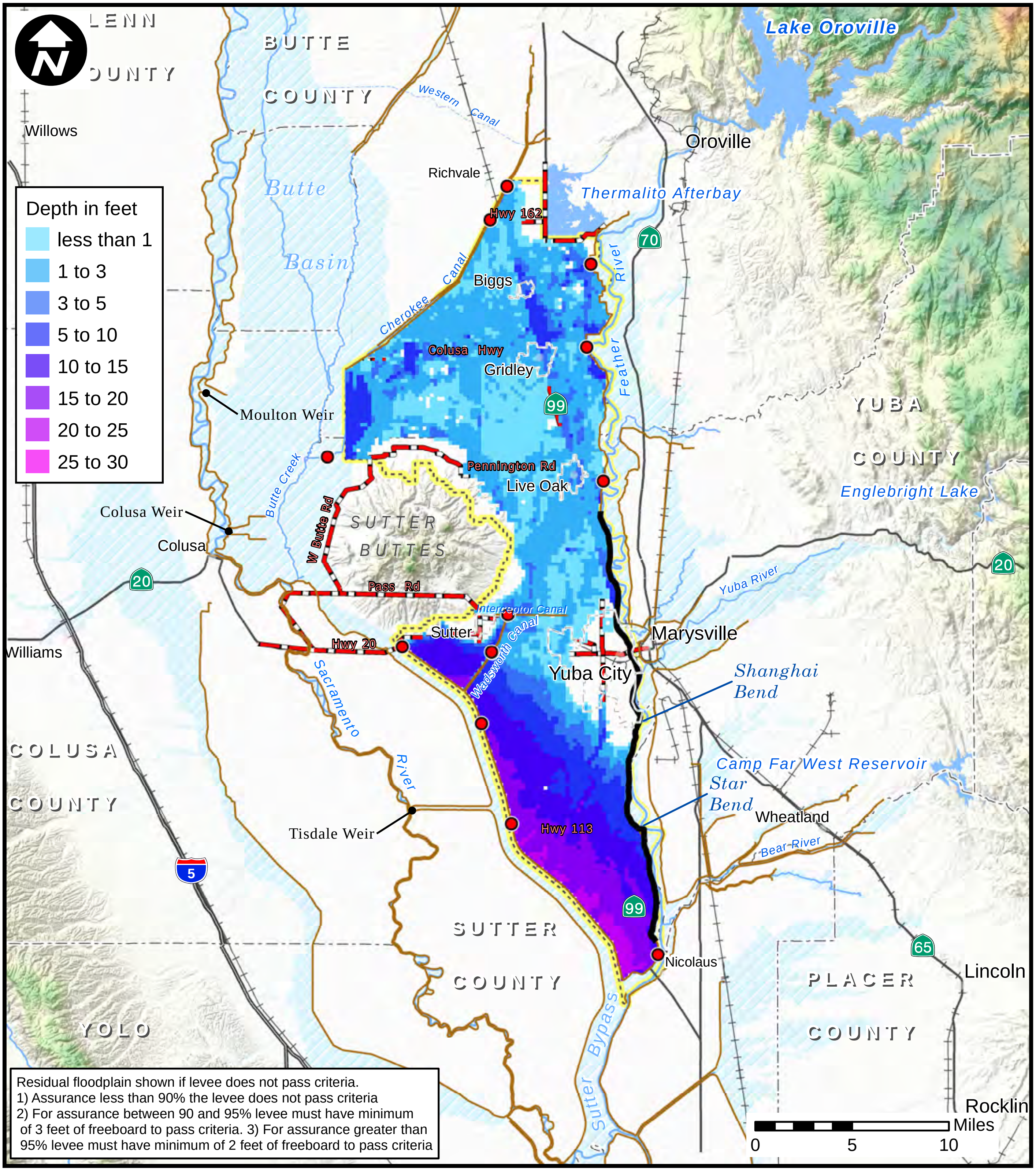
4% (1/25) ACE FLOODPLAIN ALTERNATIVE SB-7 FIX IN PLACE FEATHER RIVER, SUNSET WEIR TO LAUREL AVE

U.S. ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT

Prepared by Jim Mars

FEB 2013

PLATE 60



Legend

Federal Levee	Levee Fails Criteria
Alternative SB-7	Evacuation Routes
River or Stream	Highway
Lake or Reservoir	Railroad
Designated Floodways	County Boundary
Study Area Extent	City Limit

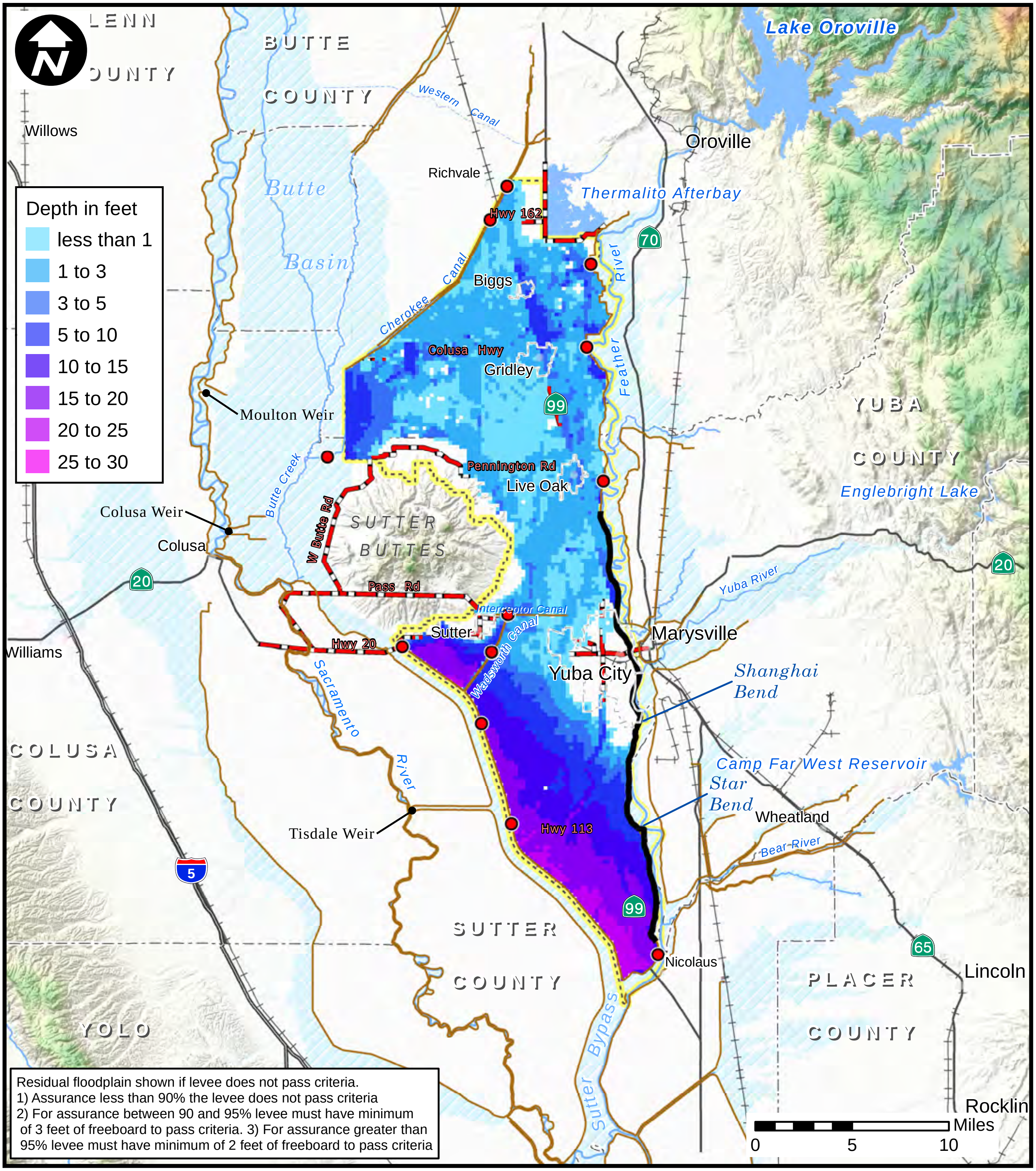
SUTTER BASIN PILOT FEASIBILITY STUDY
SUTTER BASIN, CALIFORNIA

2% (1/50) ACE FLOODPLAIN ALTERNATIVE SB-7 FIX IN PLACE FEATHER RIVER, SUNSET WEIR TO LAUREL AVE

U.S. ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT

Prepared by Jim Mars

FEB 2013



Legend

Federal Levee	Levee Fails Criteria
Alternative SB-7	Evacuation Routes
River or Stream	Highway
Lake or Reservoir	Railroad
Designated Floodways	County Boundary
Study Area Extent	City Limit

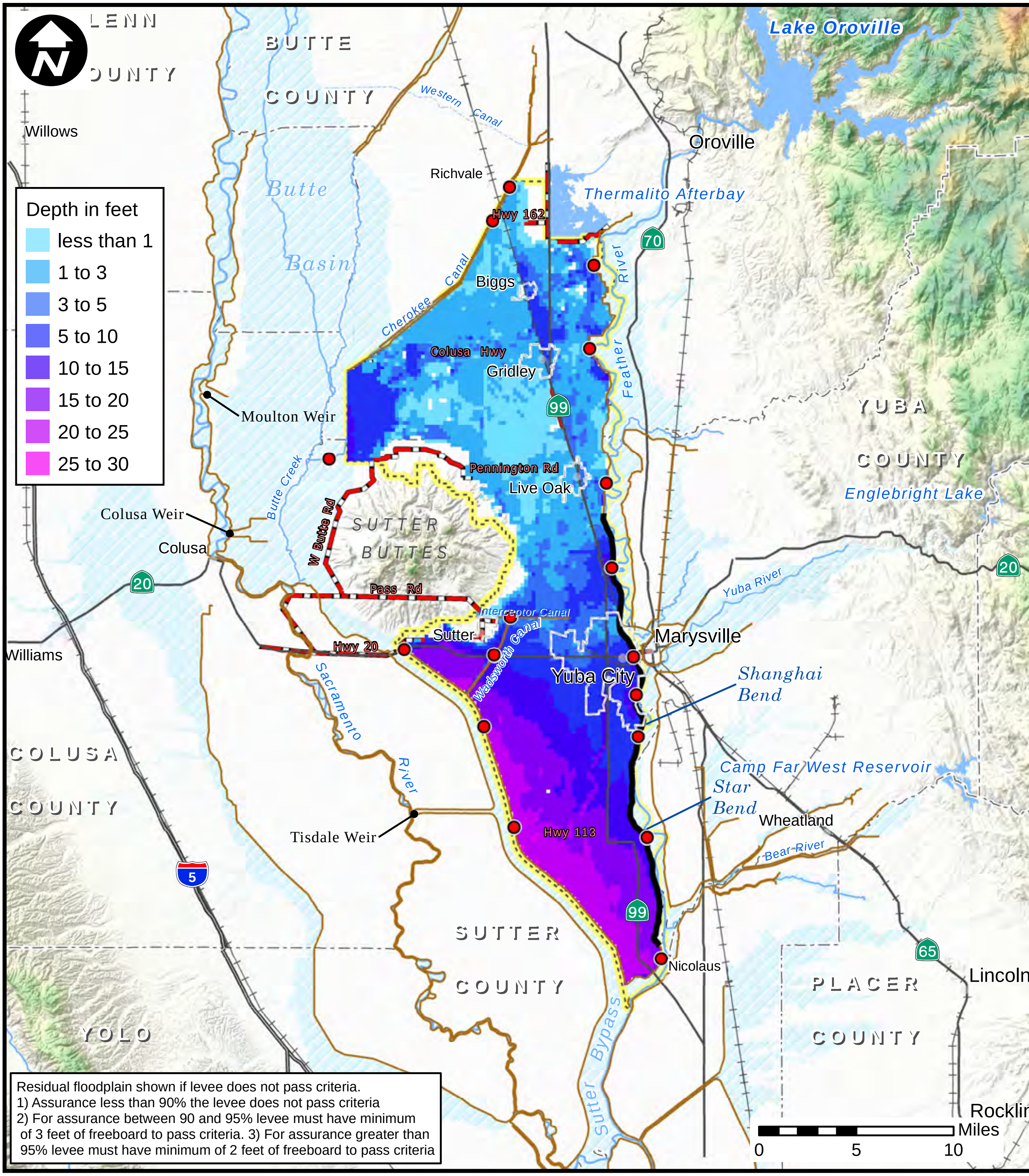
SUTTER BASIN PILOT FEASIBILITY STUDY
SUTTER BASIN, CALIFORNIA

1% (1/100) ACE FLOODPLAIN ALTERNATIVE SB-7 FIX IN PLACE FEATHER RIVER, SUNSET WEIR TO LAUREL AVE

U.S. ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT

Prepared by Jim Mars

FEB 2013



Legend

Federal Levee	Levee Fails Criteria
Alternative SB-7	Evacuation Routes
River or Stream	Highway
Lake or Reservoir	Railroad
Designated Floodways	County Boundary
Study Area Extent	City Limit

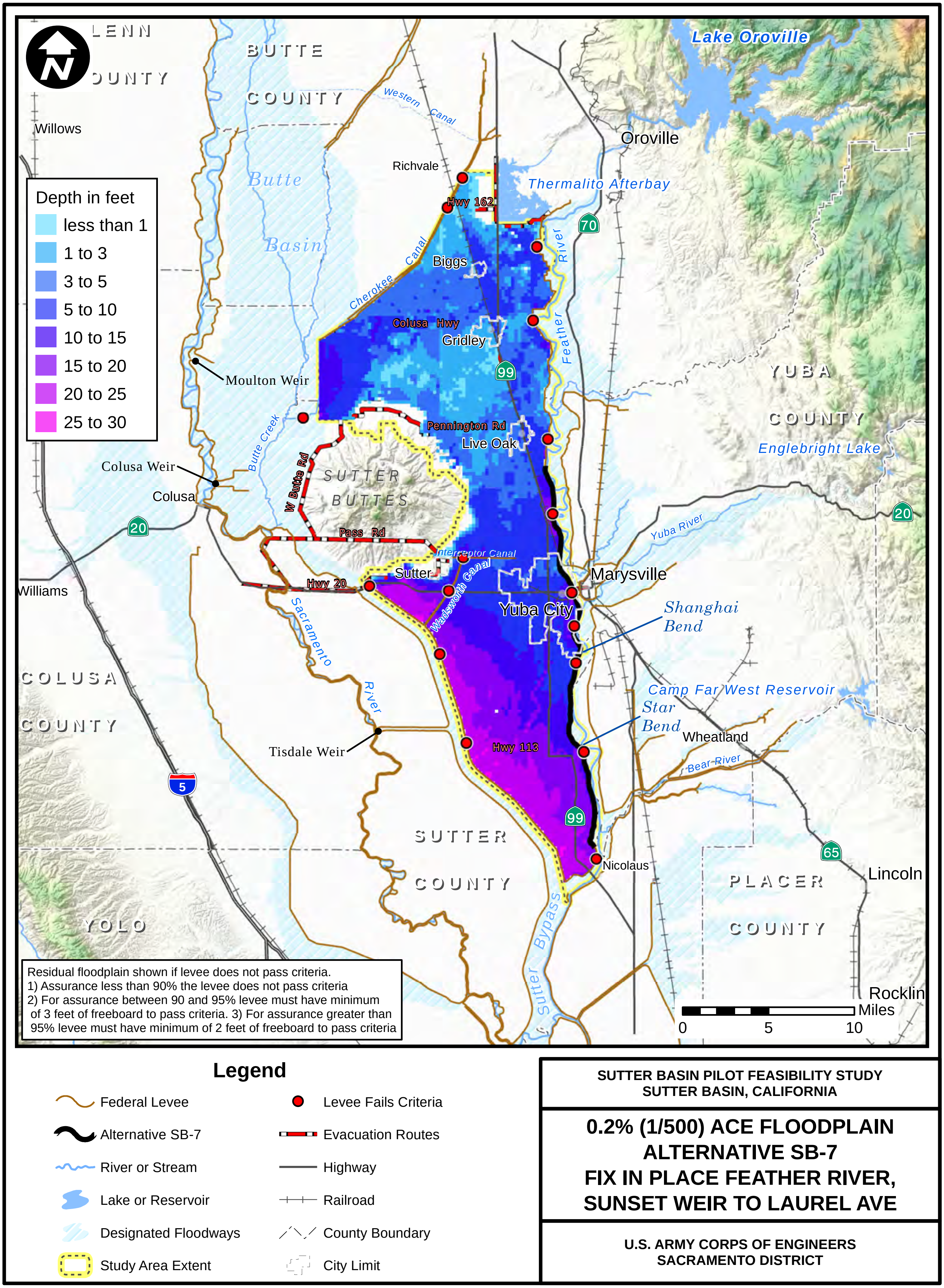
SUTTER BASIN PILOT FEASIBILITY STUDY
SUTTER BASIN, CALIFORNIA

0.5% (1/200) ACE FLOODPLAIN ALTERNATIVE SB-7 FIX IN PLACE FEATHER RIVER, SUNSET WEIR TO LAUREL AVE

U.S. ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT

Prepared by Jim Mars

FEB 2013



SUTTER BASIN PILOT FEASIBILITY STUDY
SUTTER BASIN, CALIFORNIA

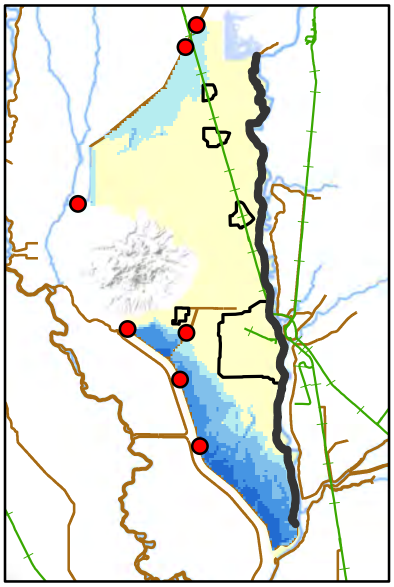
0.2% (1/500) ACE FLOODPLAIN
ALTERNATIVE SB-7
FIX IN PLACE FEATHER RIVER, SUNSET WEIR TO LAUREL AVE

U.S. ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT

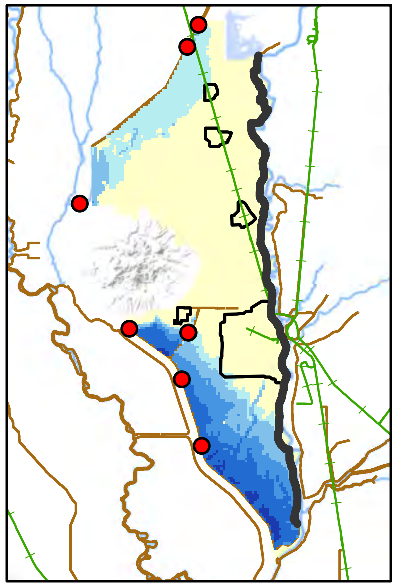
Prepared by Jim Mars

FEB 2013

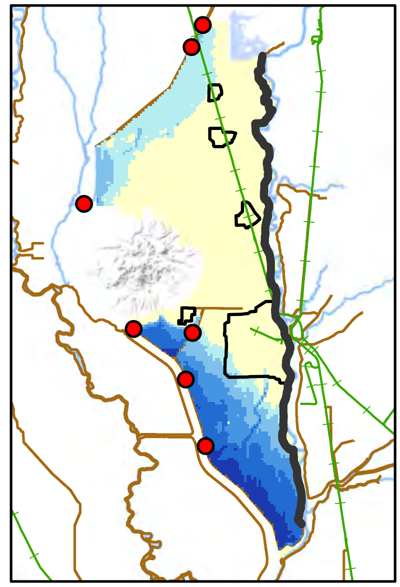
PLATE 64



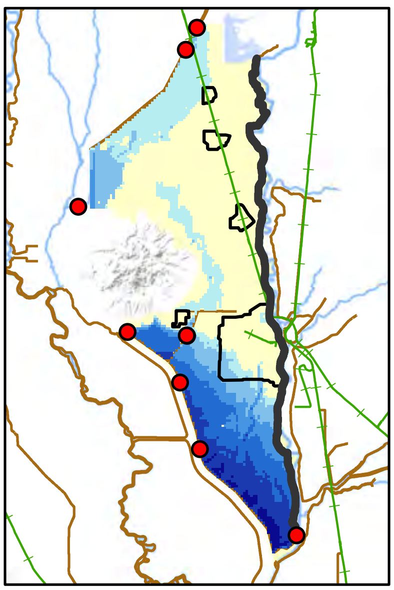
50% (1/2) ACE



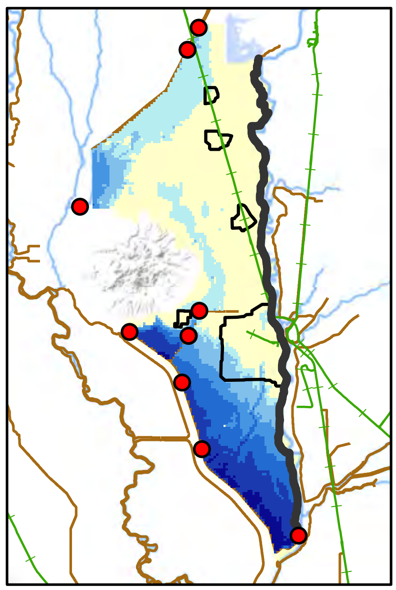
10% (1/10) ACE



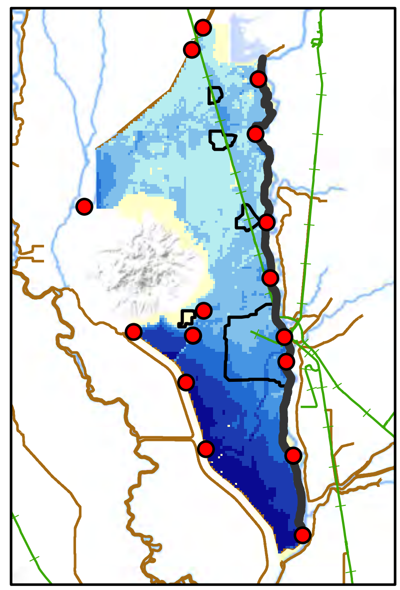
4% (1/25) ACE



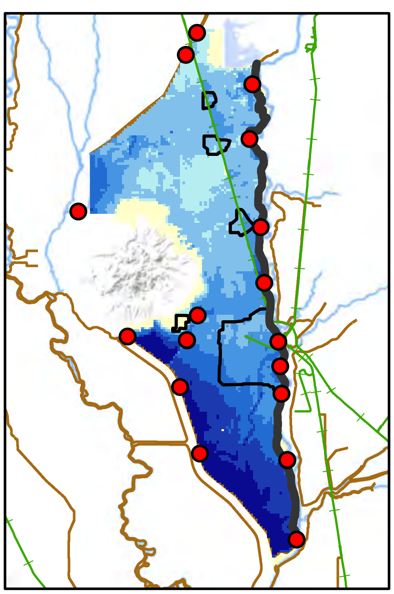
2% (1/50) ACE



1% (1/100) ACE



0.5% (1/200) ACE



0.2% (1/500) ACE

Depth

(ft)

- less than 2
- 2 to 6
- 6 to 10
- 10 to 15
- 15 to 20
- greater than 20

Railroad

Alternative

Levee Fails R&U Criteria

NOTE: Breach simulation shown if levee does not pass assurance criteria.1) Assurance less than 90% the levee does not pass criteria 2) For assurance between 90 and 95% levee must have minimum of 3 feet of freeboard to pass criteria. 3) For assurance greater than 95% levee must have minimum of 2 feet of freeboard to pass criteria

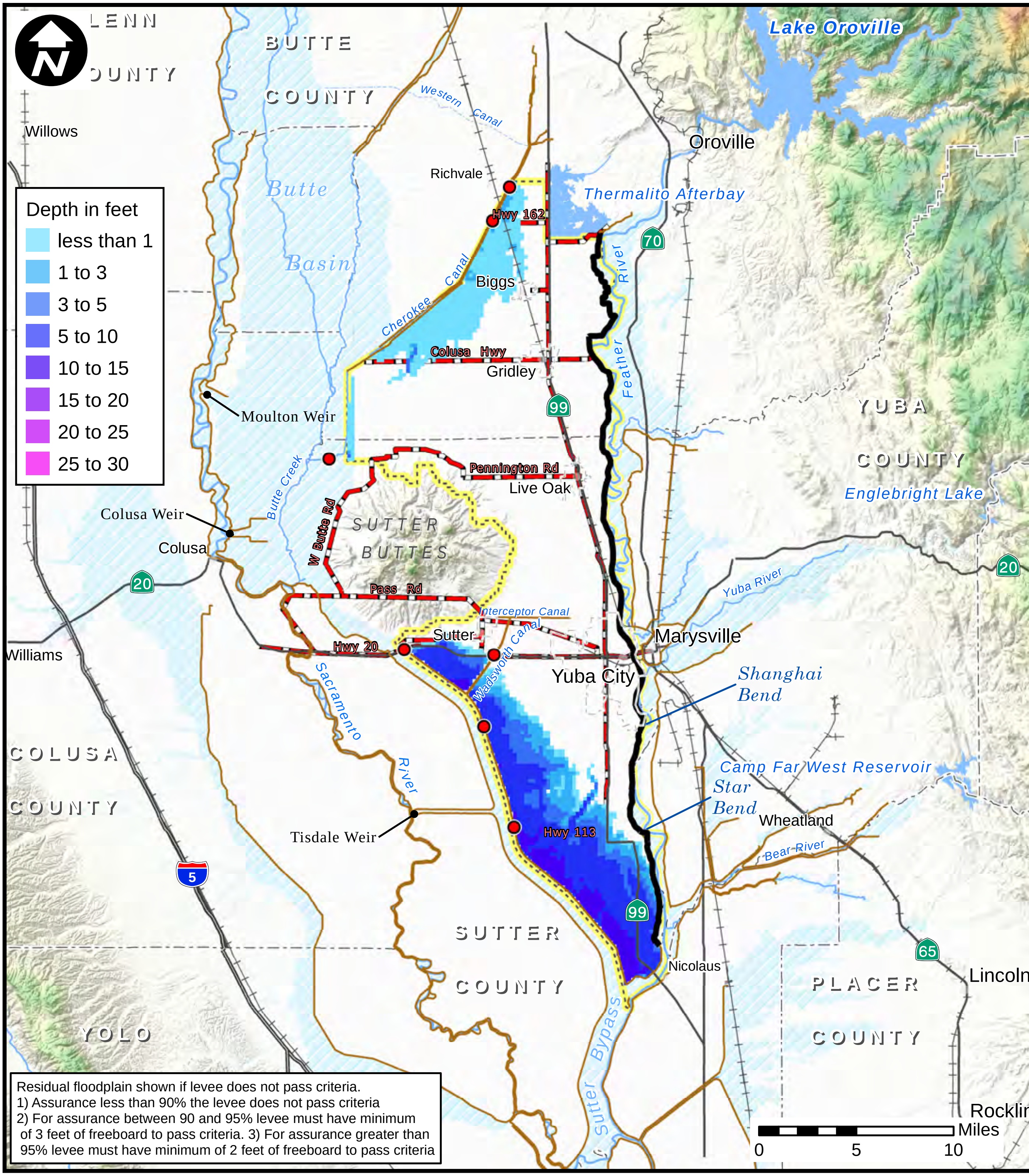
0 10 20 Miles

N

SUTTER BASIN PILOT FEASIBILITY STUDY
SUTTER BASIN, CALIFORNIA

R&U ASSURANCE FLOODPLAINS ALTERNATIVE SB-8 FIX-IN-PLACE THERMALITO TO LAUREL AVE

U.S. ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT



Residual floodplain shown if levee does not pass criteria.
1) Assurance less than 90% the levee does not pass criteria
2) For assurance between 90 and 95% levee must have minimum of 3 feet of freeboard to pass criteria. 3) For assurance greater than 95% levee must have minimum of 2 feet of freeboard to pass criteria

Legend

- Federal Levee
- Alternative SB-8
- River or Stream
- Lake or Reservoir
- Designated Floodways
- Study Area Extent
- Levee Fails Criteria
- Evacuation Routes
- Highway
- Railroad
- County Boundary
- City Limit

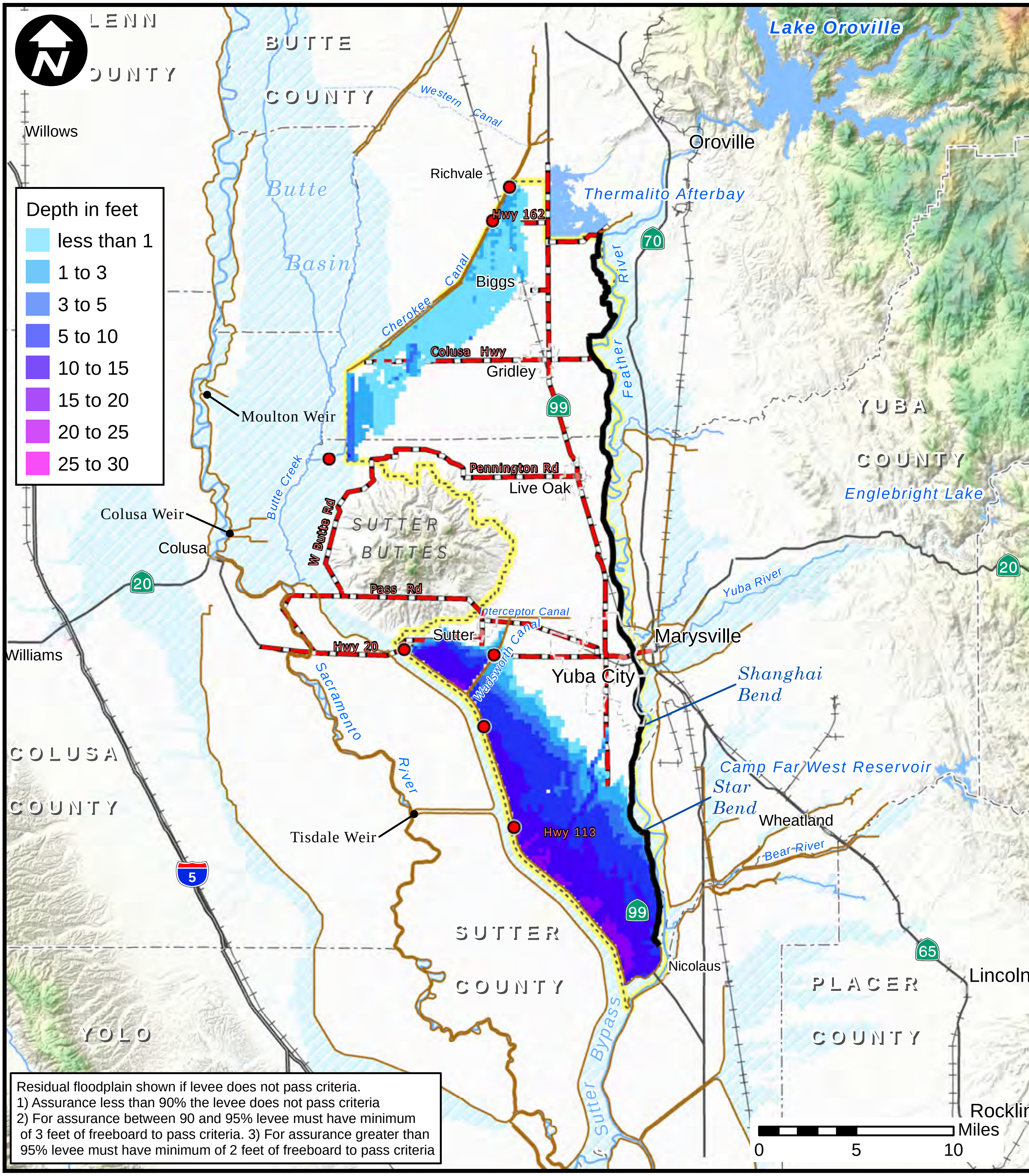
SUTTER BASIN PILOT FEASIBILITY STUDY
SUTTER BASIN, CALIFORNIA

50% (1/2) ACE FLOODPLAIN ALTERNATIVE SB-8 FIX IN PLACE FEATHER RIVER, THERMALITO TO LAUREL AVE

U.S. ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT

Prepared by Jim Mars

FEB 2013



Legend

- Federal Levee
- Alternative SB-8
- River or Stream
- Lake or Reservoir
- Designated Floodways
- Study Area Extent
- Levee Fails Criteria
- Evacuation Routes
- Highway
- Railroad
- County Boundary
- City Limit

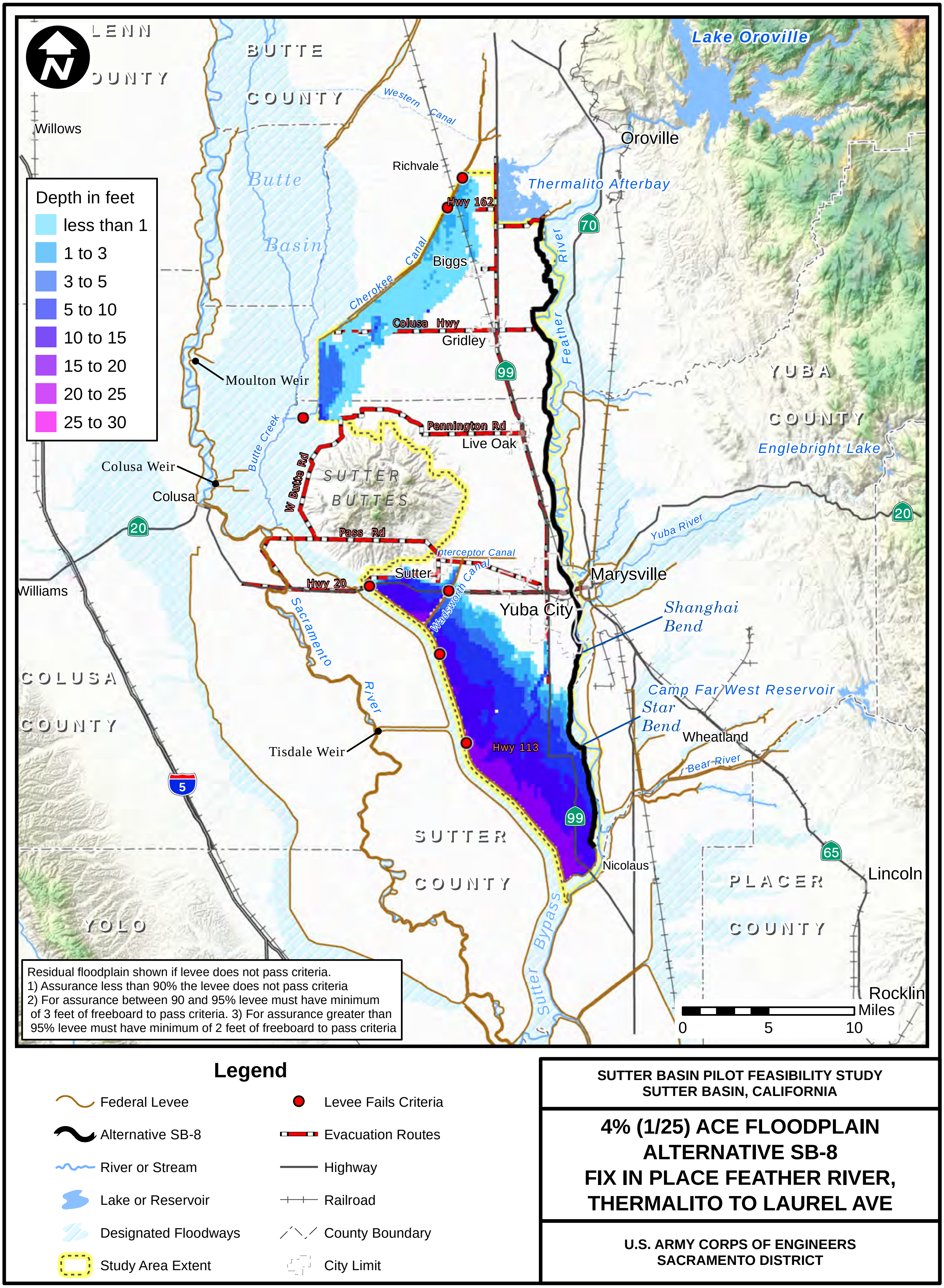
SUTTER BASIN PILOT FEASIBILITY STUDY
SUTTER BASIN, CALIFORNIA

10% (1/10) ACE FLOODPLAIN ALTERNATIVE SB-8 FIX IN PLACE FEATHER RIVER, THERMALITO TO LAUREL AVE

U.S. ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT

Prepared by Jim Mars

FEB 2013



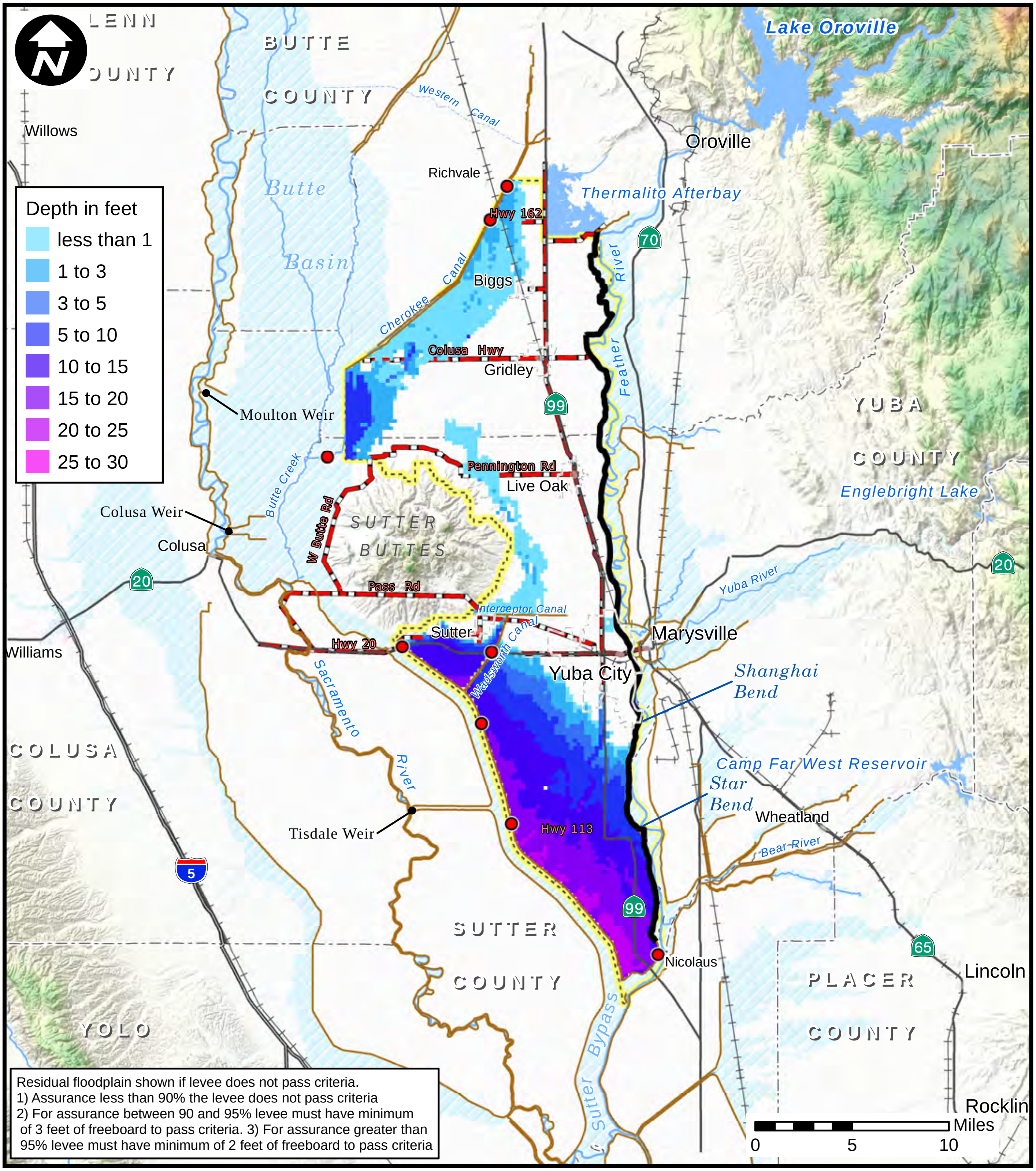
SUTTER BASIN PILOT FEASIBILITY STUDY
SUTTER BASIN, CALIFORNIA

4% (1/25) ACE FLOODPLAIN ALTERNATIVE SB-8 FIX IN PLACE FEATHER RIVER, THERMALITO TO LAUREL AVE

U.S. ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT

Prepared by Jim Mars

FEB 2013



Legend

Federal Levee	Levee Fails Criteria
Alternative SB-8	Evacuation Routes
River or Stream	Highway
Lake or Reservoir	Railroad
Designated Floodways	County Boundary
Study Area Extent	City Limit

SUTTER BASIN PILOT FEASIBILITY STUDY
SUTTER BASIN, CALIFORNIA

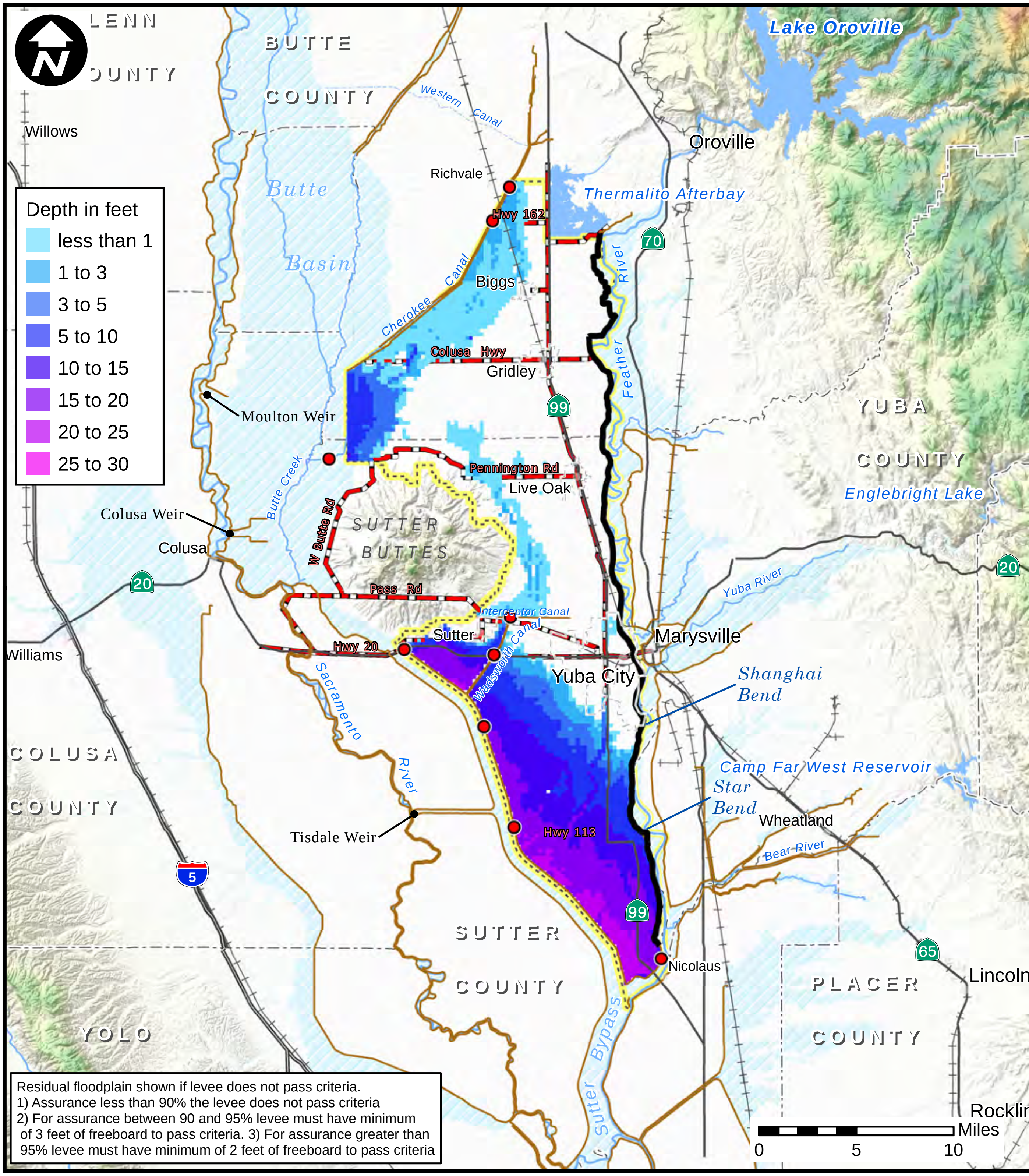
2% (1/50) ACE FLOODPLAIN ALTERNATIVE SB-8 FIX IN PLACE FEATHER RIVER, THERMALITO TO LAUREL AVE

U.S. ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT

Prepared by Jim Mars

FEB 2013

PLATE 69



Legend

- Federal Levee
- Alternative SB-8
- River or Stream
- Lake or Reservoir
- Designated Floodways
- Study Area Extent
- Levee Fails Criteria
- Evacuation Routes
- Highway
- Railroad
- County Boundary
- City Limit

SUTTER BASIN PILOT FEASIBILITY STUDY
SUTTER BASIN, CALIFORNIA

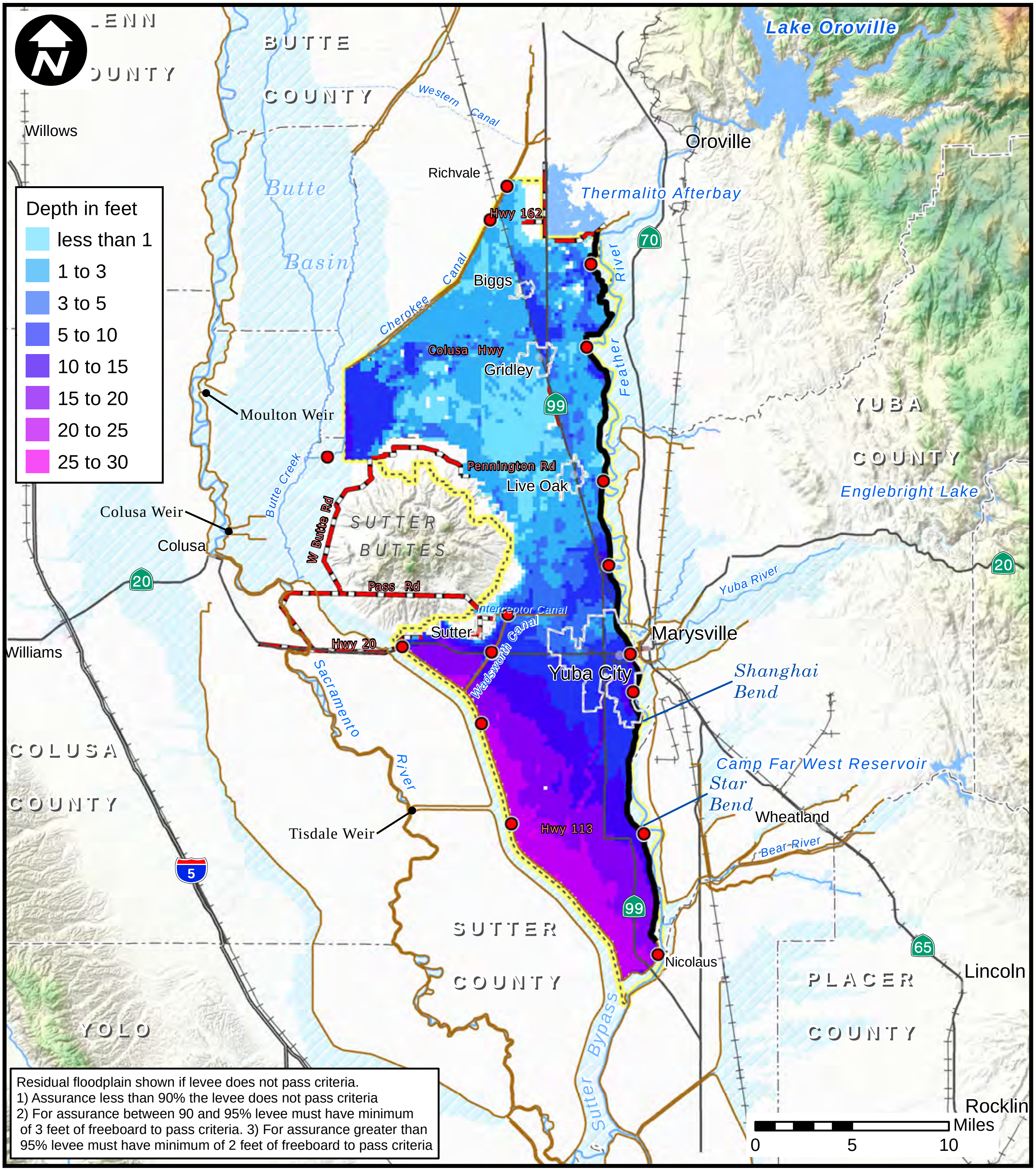
1% (1/100) ACE FLOODPLAIN ALTERNATIVE SB-8 FIX IN PLACE FEATHER RIVER, THERMALITO TO LAUREL AVE

U.S. ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT

Prepared by Jim Mars

FEB 2013

PLATE 70



Legend

Federal Levee	Levee Fails Criteria
Alternative SB-8	Evacuation Routes
River or Stream	Highway
Lake or Reservoir	Railroad
Designated Floodways	County Boundary
Study Area Extent	City Limit

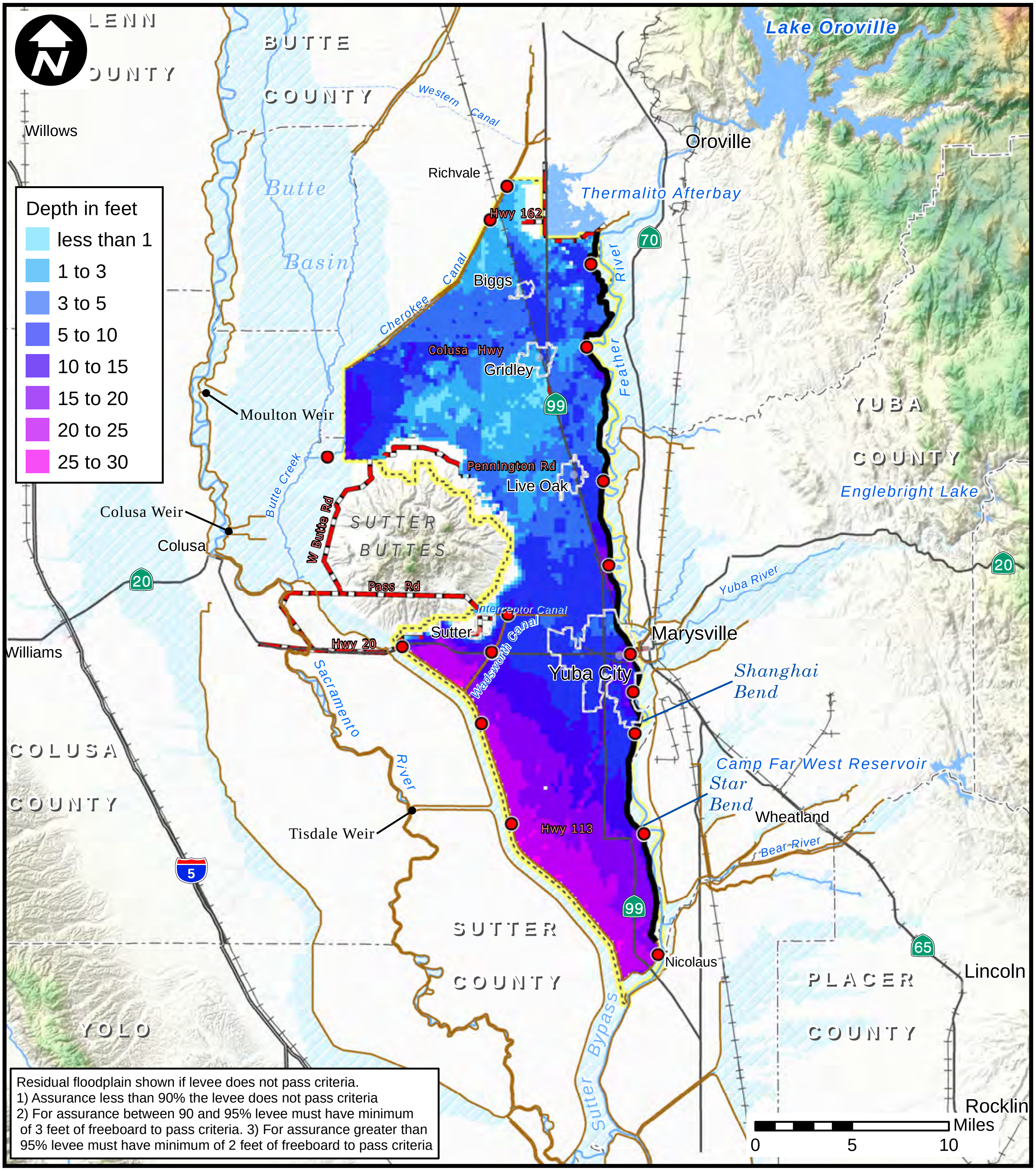
SUTTER BASIN PILOT FEASIBILITY STUDY
SUTTER BASIN, CALIFORNIA

0.5% (1/200) ACE FLOODPLAIN ALTERNATIVE SB-8 FIX IN PLACE FEATHER RIVER, THERMALITO TO LAUREL AVE

U.S. ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT

Prepared by Jim Mars

FEB 2013



Legend

Federal Levee	Levee Fails Criteria
Alternative SB-8	Evacuation Routes
River or Stream	Highway
Lake or Reservoir	Railroad
Designated Floodways	County Boundary
Study Area Extent	City Limit

SUTTER BASIN PILOT FEASIBILITY STUDY
SUTTER BASIN, CALIFORNIA

0.2% (1/500) ACE FLOODPLAIN ALTERNATIVE SB-8 FIX IN PLACE FEATHER RIVER, THERMALITO TO LAUREL AVE

U.S. ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT

Prepared by Jim Mars

FEB 2013

PLATE 72

ATTACHEMENT A

Memorandum for File:

Sutter Basin Pilot Feasibility Study,

Hydraulic Analysis of Refined Alternatives

8 June 2012

CESPK-ED-HA 8 June, 2012
23 Oct, 2012 Rev

MEMORANDUM FOR FILE: Sutter Basin Pilot Feasibility Study

SUBJECT: Hydraulic Analysis of Refined Alternatives.

1. REFERENCES:

a. DWR, 2012, Urban Levee Design Criteria, State of California Department of Water Resources, May 2012
b. USACE, 1957, Levee and Channel Profiles, Sacramento River Flood Control Project, File No. 50-10-3334, 4-sheets. 15 March 1957
c. USACE, 1995, Engineering and Design Hydrologic Engineering Requirements for Flood Damage Reduction Studies, EM 1110-2-1419, 31 Jan 1995.
d. USACE, 2002, Sacramento San Joaquin Comprehensive Study, Appendix B-Synthetic Hydrology, December 2002
e. USACE, 2008, Yuba River Basin Project, General Reevaluation Project, Appendix A, Synthetic Hydrology and Reservoir Operations Technical Documentation, April 2004 (Corrected June 2008).
f. USACE, 2010, USACE Process for the National Flood Insurance Program (NFIIP) Levee System Evaluation. 31 August 2010.

2. PURPOSE:

The purpose of this memorandum is to describe hydraulic analysis conducted in support of the Sutter Basin Feasibility Study. A map of the watershed is included as Plate 1 and a map of the study area is included as Plates 2 and 3. The memo documents refined analysis of the existing conditions, without project conditions and alternatives. Identification and evaluation of the alternatives that are refined in this analysis are presented in the report, Sutter Basin Feasibility Study, Progress Document 1, Without Project and Alternative Development.

All elevations provided herein are relative to the NAVD88 vertical datum and NAD83 Horizontal datum. Horizontal coordinates are projected to the California State Plane Zone III coordinate system. The conversion between NAVD88 and NGVD29 ranges from 2.3 to 2.4 feet in this area. Expressed as an equation, the conversion is Elevation (NGVD29) = Elevation (NAVD88) minus 2.40 feet.

3. BACKGROUND:

a. General. A high risk of flooding from levee failure threatens the public safety of approximately 80,000 people, as well as property and critical infrastructure throughout the Sutter Basin study area. Past flooding has caused loss of life and extensive economic damages. Recent geotechnical analysis and evaluation of historical performance during past floods indicate the project levees do not meet U.S. Army Corps of Engineers (USACE) levee design standards and are at risk of breach failure at stages less than overtopping. Within the study area, as throughout the Sacramento Valley, floodplain and native habitats have been lost or degraded. Federally listed species and other special status species that are dependent on floodplain habitats have declined. Opportunities exist to restore land formerly converted by mining or agriculture to more natural habitats through Ecosystem Restoration (ER) in conjunction with flood risk management (FRM). There are also opportunities to provide outdoor recreational features on FRM and ER project lands. The purpose of the Sutter Basin Feasibility Study is to address FRM in conjunction with ER and recreation.

b. Alternatives. Alternative plans were evaluated through an iterative planning process. The alternatives evaluated in this memorandum are considered to be the refined array and were the outcome of multi-disciplinary analysis at two levels of increasing detail. Throughout this process the concept of absolute accuracy versus relative accuracy was considered. At each level of analysis the assessment of the existing and without project conditions was improved. Although it would appear that every plan should be compared to the most accurate assessment of existing conditions, this is not necessary because the relative accuracy between plans is sufficient to select the most optimal plan to move forward.

Conceptual alternatives were developed from a broad array of measures. The measures were evaluated at a qualitative level of detail using hydraulic assumptions and calculations. The measures were then combined into conceptual alternatives during a planning Charrette attended by the project sponsors and subject matter experts. Development of the conceptual alternatives is described in Progress Document 1.

Refined alternatives were derived from the conceptual alternatives. The conceptual alternatives described above were evaluated using qualitative and quantitative engineering analyses. Analyses included floodplain hydraulic modeling, cost estimating, and economic benefit estimations. The level of detail was limited to that required to decide which plans to carry forward. Results were evaluated at a combined VE study and planning charette attended by the project sponsors and subject matter experts. At the conclusion of the planning charette, a refined array of alternatives was identified for further analysis. Analysis of the refined array of alternatives is described in this report.

4. STUDY AREA:

a. General. The study area covers approximately 300 square miles and is approximately 43 miles long and 9 miles wide. The primary sources of flooding within the study area are the Butte Basin, Sutter Bypass, Feather River, Cherokee Canal, Wadsworth Canal, and local interior drainage.

The study area includes the communities of Yuba City, Live Oak, Gridley, Biggs, and Sutter with a total population of approximately 80,000. Yuba City is the largest community in the study area, with a population of approximately 65,000. A map of population density within the study area is provided in Plate 4. The majority of land use in the study area is related to agricultural. A map of land use types in the study area is presented in Plate 5.

b. Topography. Elevations within the study area range from 110 ft NAVD88 in the north to 30 ft NAVD88 in the south. The study area has a general slope from northeast to south west. The general slope of the study area is interrupted by two major linear features which would impact hydraulic conveyance within the study area if a levee breach were to occur. The raised embankment of the Union Pacific Railroad traverses the study area in a north south alignment. The Sutter Bypass east levee traverses the study area in a north south alignment. A topographic map of the study area is presented in Plate 2.

c. Stream Gages: A list of applicable stream gages within the study area is provided in Table 1. The stream gages are operated by the United States Geological Survey (USGS) and California Department of Water resources. Steam gages shown on Plate 7.

Table 1 Stream Gages, Sutter Basin Study Area

Gage Name	Area (Sq Mi)	Agency	Gage Number	Period of Record	Type
Bear R Nr Wheatland Ca	292	USGS	11424000	1928-2010	S,Q
Bear River at Pleasant Grove	300	DWR	A06535	1987-2010	S,Q
Butte Creek near Gridley	NA	DWR	A04150	1991-1999	S,Q
Butte Slough at Outfall Gates near Colusa	NA	WDL	A02967	1992-2010	S
Butte Slough near Meridian	NA	WDL	A02972	1981-2010	S,Q
Cherokee Canal nr Gridley	NA	DWR	A00910	1991-1998	S,Q
Cherokee Canal nr Richvale	NA	DWR	A02984	1976-2010	S,Q
Camp Far West Reservoir	NA	DWR	A65105	1998-2010	Q
Colusa Weir Spill to Butte Basin near Colusa	NA	WDL	A02981	1975-2010	S,Q
Deer C Nr Smartville CA	84.6	USGS	11418500	1935-2010	S,Q
Feather River at Nicholaus	5,921	DWR	A05103	1942-2010	S,Q(P)
Feather River at Oroville	3,624	USGS	11407000	1902-2010	S,Q
Feather River at Yuba City	3,974	DWR	A05135	1964-2010	S
Feather River near Gridley	3,676	DWR	A05165	1964-2010	S,Q
Moulton Weir Spill to Butte Basin nr Colusa	NA	DWR	A02986		
Sacramento R at Colusa Ca	12,090	USGS	11389500	1941-2010	S,Q
Sacramento R at Verona Ca	21,251	USGS	11425500	1929-2010	S,Q
Sacramento R Blw Wilkins Slough nr Grimes Ca	12,915	USGS	11390500	1931-2010	S,Q
Sacramento River at Butte Slough Outfall Gates	NA	DWR	A02400	1992-2004	S
Sacramento River at Fremont Weir (East)	NA	DWR	A02160	1935-2010	S
Sacramento River at Fremont Weir (West)	NA	DWR	A02170	1934-2010	S
Sacramento River at Knights Landing	14,535	DWR	A02200	1982-2010	S
Sacramento Slough near Karnak	NA	DWR	A02925	1981-2010	S
Sutter Bypass at R.D. 1500 P.P. near Karnak	NA	DWR	A02927	1975-2010	S
Sutter Bypass Channel at Pumping Plant #1	NA	DWR	SB1	2008-2010	S
Sutter Bypass Channel at Pumping Plant #2	NA	DWR	SB2	2008-2010	S
Sutter Bypass Channel at Pumping Plant #3	NA	DWR	SB3	2008-2010	S
Tisdale Weir near Grimes	NA	DWR	A02960	1975-2010	S,Q
Willow Slough near Nicolaus	NA	DWR	A02943	1991-2010	S
Yolo Bypass nr Woodland Ca	NA	USGS	11453000	1939-2011	S,Q
Yuba R blw Englebright Dam near Smartsville	1,108	USGS	11418000	1941-2011	S,Q
Yuba R Nr Marysville CA	1,339	USGS	11421000	1940-2011	S,Q
Wadsworth Canal near Sutter (lower)	96	DWR	A05927	1982-1997	S,Q
Wadsworth Canal near Sutter (upper)	96	DWR	A05929	1976-1997	S,Q
Note: S-Stage, Q-Discharge, NA- Not Available, (Partial Record)					

5. SOURCES OF FLOODING:

The following describes significant sources of flooding within the study area.

a. Butte Basin. The Butte Basin is a natural overflow and flood storage area north west of the Sutter Buttes and east of the Sacramento River. The basin provides approximately 1 million acre-feet of transitory storage at flood stage (DWR, 2010). Excess floodwaters from the Sacramento River enter the Butte Basin via overbank areas along the river and through the Moulton and Colusa weirs. Butte Creek and its tributaries, including Cherokee Canal, also flow into the Butte Basin. Outflow from the Butte Basin is regulated by hydraulic conditions of Butte Slough and floodplain topography at the upstream entrance to the Sutter Bypass. In order to maintain the flood storage capabilities within Butte Basin, California has included regulation of the overflow area in Title 23 of the California Code of Regulations. In general these standards require approval from the board for any encroachments that could reduce or impede flood flows or would reclaim any of the floodplain within the Butte Basin (DWR, 2010).

b. Sutter Bypass. The Sutter Bypass is a leveed flood control channel approximately three quarters of a mile wide, bordered on each side by levees. The bypass is an integral feature of the Sacramento River Flood Control Project's flood bypass system. The Sutter Bypass conveys flood waters from the Butte Basin, Sacramento River, and Feather River to the confluence of the Sacramento River and Yolo Bypass at Fremont Weir.

Downstream of the Feather River, the bypass is separated into two conveyance areas by a low levee. The area east of the middle levee conveys the Feather River. This design maintains higher velocities and sediment transport capacity within the Feather River during low flow events while utilizing the large conveyance of the Sutter Bypass during larger events.

The Sutter Bypass also receives minor natural flow and agricultural return flow from Reclamation District 1660 to the west and from Wadsworth Canal and DWR pumping plants 1, 2, and 3 to the east. The Sutter Bypass is described by four hydrologic reaches based on tributary inflows; Butte Slough to Wadsworth Canal, Wadsworth Canal to Tisdale Bypass, Tisdale Bypass to Feather River, Feather River to Sacramento River.

c. Feather River. The Feather River is a major tributary to the Sacramento River, merging with the Sutter Bypass upstream from the Sacramento River and Fremont Weir. The Yuba and Bear Rivers are major tributaries to the Feather River. Two major flood management reservoirs are located within the Feather River watershed. Oroville Dam and reservoir was completed on the Feather River in 1967. The reservoir has 3,358,000 acre-feet of storage with 750,000 acre-feet of dedicated flood management space. New Bullards Bar dam and reservoir was completed on the Yuba River 1970. The reservoir has 966,000 acre-feet of storage with 170,000 acre-feet of dedicated flood management space. The Feather River is described by four hydrologic reaches based on significant inflows; Thermalito to Honcut Creek, Honcut Creek to Yuba River, Yuba River to Bear River, and Bear River to Sutter Bypass.

d. Cherokee Canal. The Cherokee Canal is a tributary to Butte Creek and the Butte Basin. The leveed canal was constructed between 1959 and 1960 by USACE. The canal drainage area is 94 square miles and varies in elevation from 70 feet to 2200 feet. The drainage area is bounded by the Feather River watershed to the east and southeast, Butte Creek and its tributaries to the north and west, and by Wadsworth Canal drainage to the south.

e. Wadsworth Canal. The Wadsworth Canal is a leveed tributary to the Sutter Bypass near the town of Sutter. The canal conveys flow from the East and West interceptor canals to the Sutter Bypass. The East and West interceptor canals collect runoff from 96 square miles of into the Wadsworth Canal.

6. RECENT FLOODS:

The following is a description of recent significant flood events within the study area. The magnitudes of historical floods are difficult to compare due to significant historical changes in the flood management system.

a. December 1955. The last major flood to damage the study area occurred in December 1955 when the west levee of the Feather River breached near Shanghai Bend. The peak flow measured at the Feather River at Oroville stream gage was 203,000cfs. This flood occurred prior to construction of Oroville and New Bullards Bar reservoirs. Therefore, the flood does not reflect existing hydrologic conditions. A hypothetical flood routing of the 1955 flood is presented in the Oroville Dam water control manual. The flood routing indicates the reservoir would have regulated the peak outflow to 150,000cfs.

b. November 1982 - March1983. Water year 1983 was a result of the “El Niño” weather phenomenon. Northern and Central California experienced flooding incidents from November through March due to numerous storms. In early May, snow water content in the Sierra exceeded 230 percent of normal, and the ensuing runoff resulted in approximately four times the average volume for Central Valley streams. System failures in the Sacramento River Basin were limited to a private levee on the Sacramento River and one failure on Cache Creek.

c. February 1986. Flooding in 1986 resulted from a series of four storms over a 9-day period during February. Rains from the first three storms saturated the ground and produced moderate to heavy runoff before the arrival of the fourth storm. Precipitation at Four Trees in the Feather River Basin set both a 24-hour rainfall record for the Sierra Nevada and the monthly record for any station in the State. System breaks in the Sacramento River Basin included disastrous levee breaks in the Olivehurst and Linda area on the Feather River, adjacent to the study area.

d. January 1995. "El Nino" conditions in the Pacific forced major storm systems directly into California during much of the winter and early spring of 1995. The largest storm systems hit California in early January and early March. The major brunt of the January storms hit the Sacramento River Basin and resulted in small stream flooding primarily due to storm drainage system failures.

e. January 1997. December 1996 was one of the wettest Decembers on record. Watersheds in the Sierra Nevada were already saturated by the time three subtropical storms added more than 30 inches of rain in late December 1996 and early January 1997. The third and most severe of these storms lasted from December 31, 1996, through January 2, 1997. Rain in the Sierra Nevada caused record flows that stressed the flood management system to capacity in the Sacramento River Basin and overwhelmed the system in the San Joaquin River Basin. Levee failures due to breaks or overtopping in the Sacramento River Basin resulted in extensive damages.

f. December 2005 - January 2006. Between 28 December 2005 and 9 January 2006, the State of California experienced a series of severe storms which impacted the levees within the Sacramento District's boundaries. Water rose a second time in April 2006, and remained high in some parts of the system until June. Many rivers and streams within the Sacramento and San Joaquin River systems ran above flood stage during these events, and there were significant erosion and seepage problems with the levees. The State of California Department of Water Resources and/or their maintaining agencies conducted the actual flood fight activities while the U.S. Army Corps of Engineers provided technical assistance to the State.

7. FLOOD RISK ASSESSMENT APPROACH

Flood risk is defined as the probability of a flood event occurring and the consequences of occurrence. Flood risk was assessed using the USACE FDA model approach and is described in the economics report. The report presents results for seven economic impact areas within the study area. A map of the economic impact areas is presented as Plate 6.

The FDA approach combines flow-frequency, stage-discharge, geotechnical fragility, and stage-damage relationships to estimate damages. Uncertainty in each relationship is incorporated by assigning uncertainty estimates and applying a Monte Carlo type approach to combine the results.

Flow-frequency, stage discharge, and geotechnical frequency relationships reflect the exterior (probability) side of the risk calculations. Inundation depth and stage-damage relationships reflect the interior (consequence) side of the risk calculations. For the probability side of the risk calculations, the hydraulic model assumptions are based on flows contained to the channel (allowed to overtop without failure). For the consequence side of the risk calculations, the hydraulic model assumptions are based on levee breach failure or simply the depth for natural overbank (non-levee) conditions.

The first step in the risk assessment approach was evaluation of potential flood sources with respect to geotechnical fragility, channel hydrology, channel hydraulics, and potential inundation patterns of a levee breach natural overbank (non-levee). Thirteen geotechnical reaches were identified. Within each of these geotechnical reaches a representative geotechnical fragility curve was developed and a stage-discharge relationship was developed using a hydraulic model (see below). Selection of the geotechnical reaches is described in detail in the geotechnical analysis. Fifteen breach sources and one non-leveed flood source locations were identified. All flood source locations identified within a geotechnical reach were assigned to the same geotechnical fragility curve location.

8. FLOOD RISK MAPS

The performance of existing Flood Risk Management features varies by reach. Performance was evaluated using the HEC-FDA computer program and is discussed in detail in the economics section. Levee performance is expressed as an assurance level (conditional non-exceedance probability) for a given median ACE hydrologic event.

Maps showing residual flood risk were developed to demonstrate FRM performance levels relative to a standard assurance criterion. The maps show inundation from any flood source that would not meet an assurance criterion. Maps were developed for each of two assurance criteria.

a. Assurance Criteria#1. This criterion was based on the deterministic approach required by FEMA for 1% ACE and DWR for 0.5% ACE. To meet this criteria a levee reach must have a minimum of 3 feet of freeboard for Hydrology and Hydraulic capacity for the given flood event. The geotechnical performance of a levee reach must meet current USACE geotechnical and civil design standards for the given design flood event. This assurance criterion was used to define residual risk maps for all Annual Chance Exceedance (ACE) events.

b. Assurance Criteria #2. This criterion was based on the NFIP levee system analysis criteria described in EC 1110-2-6067 and was adopted for use in describing the performance of all ACE events. This criterion is described as "Option 2" in the DWR Urban Levee Design Criteria. Assurance values were based on an USACE FDA risk and uncertainty analysis which included hydrologic uncertainty, hydraulic uncertainty, and geotechnical fragility curves. All values are relative to the median stage for each ACE event. 1) For assurance less than 90% the levee does not pass criteria 2) For assurance between 90 and 95% levee must have minimum of 3 feet of freeboard to pass criteria. 3) For assurance greater than 95% levee must have minimum of 2 feet of freeboard to pass criteria. Other requirements described in EC1110-2-6067 are not included. For example, operations and maintenance requirements are not included in the criteria.

9. EXISTING CONDITION CHANNEL MODEL

Water surface profiles were computed using HEC-RAS and HEC-UNET one-dimensional flow models. HEC-RAS and UNET calculate steady or unsteady gradually varied flow in natural and manmade channels by performing step-backwater calculations of the 1-D flow energy equation through a series of input geometric cross-sections with empirically defined hydraulic roughness coefficients.

An unsteady system-wide HEC-RAS model was used for the Sacramento River, Feather River, and Sutter Bypass. A steady state HEC-RAS model was used for the Wadsworth Canal. An unsteady HEC-RAS model was used for Cherokee Canal. An unsteady HEC-UNET model developed for the Sacramento-San Joaquin Comprehensive study was used for Butte Basin flood depths. A map of the HEC-RAS hydraulic models cross sections and location of boundary conditions is provided as Plate 7. The following describes hydraulic model input to the FDA hydraulic model and also used in the assessment of project performance and assurance.

a. Non-Failure Infinite Height Levee Profiles. Models were developed to evaluate two profile scenarios. Scenario A assumed all levees were infinitely high and would contain all flows without overtopping. This scenario was used to evaluate the sensitivity of downstream flow conditions relative to upstream overtopping assumptions. The resulting model profiles are provided in Plates 8, 9, 10, and 11.

b. Non-Failure Overtopping Profiles. Scenario B assumed all levees were overtopped without failure. Scenario B was used in the economic FDA analysis. The resulting model profiles are provided in Plates 8, 9, 10, and 11. As described above, these median profiles are for use in the FDA flood damage assessment model. The profiles do not account for risk and uncertainty which is required to evaluate assurance. Assurance estimates are provided in the economics report.

c. Breach Hydrographs. Simulations were performed for fifteen levee breach flood sources and one natural (non-leveed) flood source. These sources were spatially distributed throughout the study area. Breach locations were selected to represent similar levee and floodplain characteristics. All breach scenarios assume levees were overtopped without failure at all locations other than the breach location. Eight breaches were simulated on the Feather River from Thermalito to Sutter Bypass. Two breaches were simulated on the Sutter Bypass between Wadsworth Canal and Feather River. Two breaches were simulated on Cherokee Canal upstream and downstream of the Union Pacific Railroad. A single breach was simulated on Wadsworth Canal. All breach simulations assume remaining levee reaches would be overtopped without failure. In order to simplify the analysis, breaches were assumed to exist at the start of each flood hydrograph simulation.

c. Stage Uncertainty. Stage uncertainty arises from the use of simplified models to describe complex hydraulic phenomena, including the lack of detailed geometric data, misalignments of hydraulic structures, debris load, infiltration rates, embankment failures, material variability, and from errors in estimating slope and roughness factors.

A standard deviation in stage of 1.5 feet was used for hydraulic uncertainty. This value was estimated following methods in EM-1110-2-1619. The total stage uncertainty was based on the geometric mean of natural and model uncertainty. The total stage uncertainty was based on standard deviations of 0.75 ft and 1.3 feet for natural and model uncertainty respectively.

10. EXISTING CONDITION FLOODPLAIN INUNDATION MODEL

Floodplain inundation was simulated using a FLO-2D two dimensional hydrologic model of the Study Area. The without project condition FLO-2D model was modified from existing USACE models by the Sutter Butte Flood Control Agency as work in kind credit for the study. Models and results underwent Independent Technical Review and District Quality Control. The model includes significant floodplain features which can interfere with the flood conveyance in the floodplain. For example, the model includes railroad embankments and culverts. A map showing the FLO-2D model domain is provided as Plate 12.

a. Breach Scenarios. For each hydrologic frequency event, floodplain inundation breach maps were developed for the fifteen levee breaches and one natural (non-leveed) flood sources throughout the study area. The inundation maps simulate a levee breach during the flood event. The inflow to the FLO-2D model was the outflow from the HEC-RAS model. The specified frequency is not the frequency of inundation. Inundation frequency estimates must account for performance of the levee (probability of the breach). The inundation frequency is computed in the economic flood damage analysis using the geotechnical fragility curves. Simulated inundation maps for levee breaches during a 100-yr event are provided as plates 13 through 28. Digital maps generated for simulated breaches during other ACE flood events are available upon request.

11. REFINED ALTERNATIVES.

The following describes the hydraulic design of new levees, project performance, and residual floodplains for each of the refined project alternatives.

d. SB-1 No Action. Based on a review of historical conditions and proposed actions, the hydraulic conditions in the future are assumed to be the same as existing conditions. Residual flood risk maps for criteria #1 and #2 are presented in Plates 29 and 30 respectively.

e. SB-2 Minimal Fix-In-Place plus NonStructural. This alternative would increase the performance of the levee from Sunset Weir to Star Bend. Residual Flood Risk Maps were based on reducing the fragility curve to overtopping only for breach locations FR6.0R, FR5.0R, and FR4.5R. Residual flood risk maps for criteria #1 and #2 are presented in Plates 31 and 32 respectively.

f. SB-3 Yuba City Ring Levee. This alternative would involve construction of a ring levee around Yuba City. The height of the ring levee was determined by reviewing the flood elevations from the hypothetical levee breaches. Wind wave runup analysis was also conducted and the levee height was increased as necessary to provide 95% assurance from a levee breach outside the ring levee during a 0.5% (1/200) ACE flood. The hypothetical levee breach simulations were conducted for the 0.2% (1/500) ACE flood event with the levee in place. The resulting levee design profile is provided as Plate 33. Residual flood risk maps were based on reducing the fragility curve to overtopping only for breach locations FR5.0R and FR4.5R. Residual flood risk maps for criteria #1 and #2 are presented in Plates 34 and 35 respectively.

g. SB-4 Yuba City J-Levee. This alternative would involve fixing the levees from Thermalito to Shanghai Bend and construction of a partial ring levee around Yuba City. The height of the new portion of levee was determined by reviewing the flood elevations from the hypothetical levee breaches. Wind wave runup analysis was also conducted and the levee height was increased as necessary to provide 95% assurance from a levee breach during a 0.5% (1/200) ACE flood in the unfixed levees. The hypothetical levee breach simulations were conducted for the 0.2% (1/500) ACE flood event with the levee in place. The resulting levee design profile is provided as Plate 36.Residual flood risk maps were based on reducing the fragility curve to overtopping only for breach locations on the Feather River FR9.0R, FR8.0R, FR7.0R, FR6.0R, FR5.0R, and FR4.5R. Residual flood risk maps for criteria #1 and #2 are presented in Plates 37 and 38 respectively.

h. SB-5 Fix in Place Feather River, Thermalito to Star Bend. This alternative would involve fixing the levees from Thermalito to Star Bend. The hypothetical levee breach simulations are the same as the no action plan. Residual flood risk maps were based on reducing the fragility curve to overtopping only for breach locations on the Feather River FR9.0R, FR8.0R, FR7.0R, FR6.0R, FR4.5R. Residual flood risk maps for criteria #1 and #2 are presented in Plates 39 and 40 respectively.

i. SB-6 Fix in Place Feather River, Sutter Bypass and Wadsworth Canal. This alternative would involve fixing the east levee of the Sutter Bypass downstream of Wadworth Canal, Wadsworth Canal south levee and Feather River west levee. The hypothetical levee breach simulations are the same as the no action plan. Flood Residual flood risk maps were based on reducing the fragility curve to overtopping only for all breach locations except BB1.0, CC2.0L,CC1.0L, SB 5.0L, and BW2.0R. Residual flood risk maps for criteria #1 and #2 are presented in Plates 41 and 42 respectively.

j. SB-7 Fix-In-Place Sunset Weir to Laurel Avenue . This alternative would increase the performance of the levee from Sunset Weir to 2200 feet downstream of Laurel Ave. Residual Flood Risk Maps were based on reducing the fragility curve to overtopping only for breach locations FR6.0R, FR5.0R, and FR4.5R, and FR4.0R. Residual flood risk maps for criteria #1 and #2 are presented in Plates 43 and 44 respectively.

k. SB-8 Fix in Place Feather River, Thermalito to Laurel Avenue. This alternative would involve fixing the levees from Thermalito to 2200 feet downstream of Laurel Ave. The hypothetical levee breach simulations are the same as the no action plan. Residual flood risk maps were based on reducing the fragility curve to overtopping only for breach locations on the Feather River FR9.0R, FR8.0R, FR7.0R, FR6.0R, FR4.5R, and FR4.0R. Residual flood risk maps for criteria #1 and #2 are presented in Plates 45 and 46 respectively.

12. CONCLUSIONS

For questions on the technical content of this report, contact Peter Blodgett, P.E., Hydraulic Design Section, (916) 557-7529.

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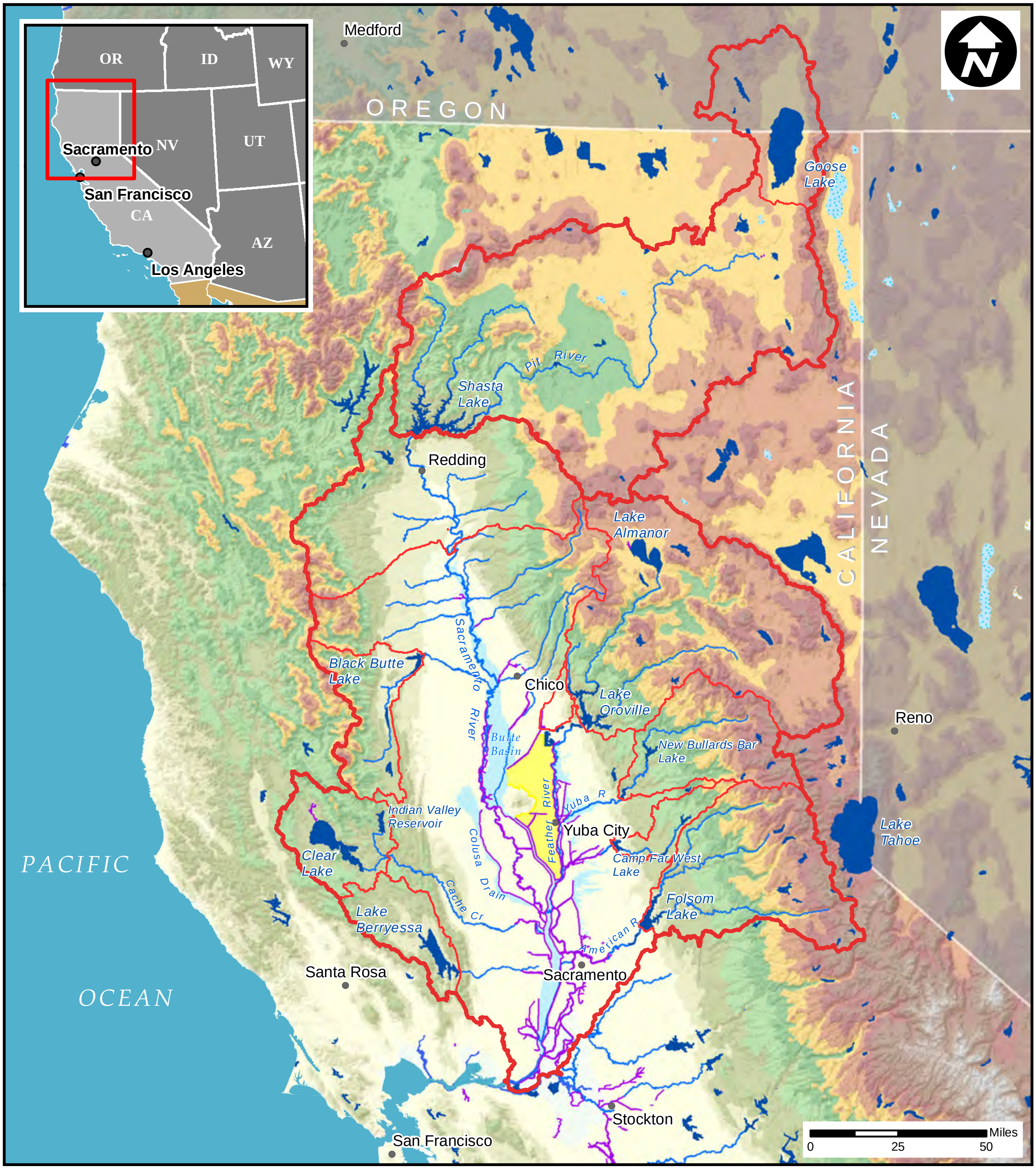
Sacramento District,
U.S. Army Corps of Engineers



Legend

Study Area Extent

Lake or Reservoir

Sacramento Basin

River or Stream

Watershed Boundaries

Federal Levees

Designated Floodways

City

SUTTER BASIN PILOT FEASIBILITY STUDY
SUTTER BASIN, CALIFORNIA

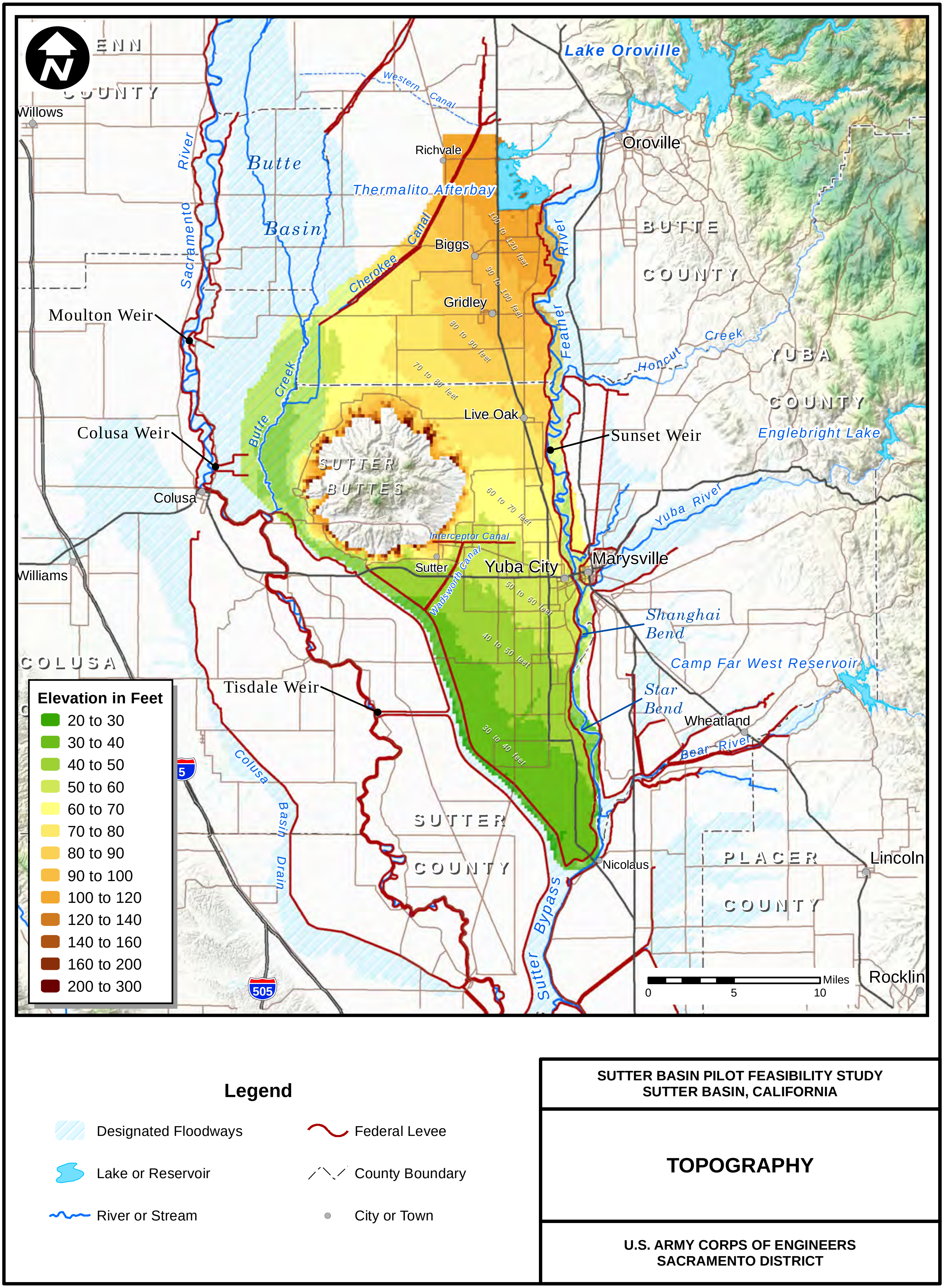
SACRAMENTO RIVER WATERSHED

U.S. ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT

Prepared by Jim Mars

OCT 2012

PLATE 1



SUTTER BASIN PILOT FEASIBILITY STUDY
SUTTER BASIN, CALIFORNIA

TOPOGRAPHY

U.S. ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT

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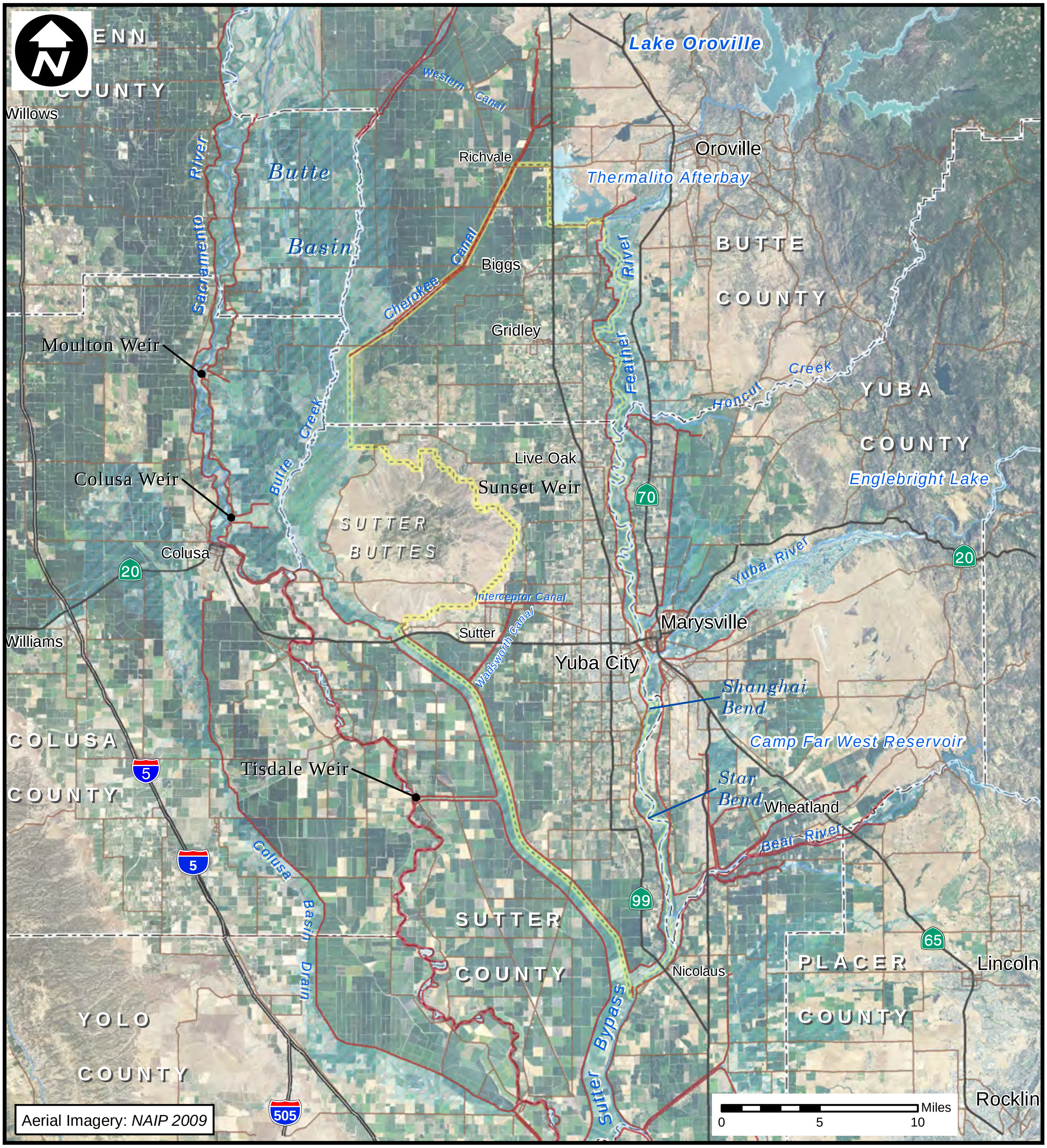
PLATE 2



Legend

- Study Area Extent
- Designated Floodways
- Lake or Reservoir
- River or Stream
- Federal Levee
- County Boundary
- City or Town

SUTTER BASIN PILOT FEASIBILITY STUDY
SUTTER BASIN, CALIFORNIA

AERIAL IMAGERY

U.S. ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT

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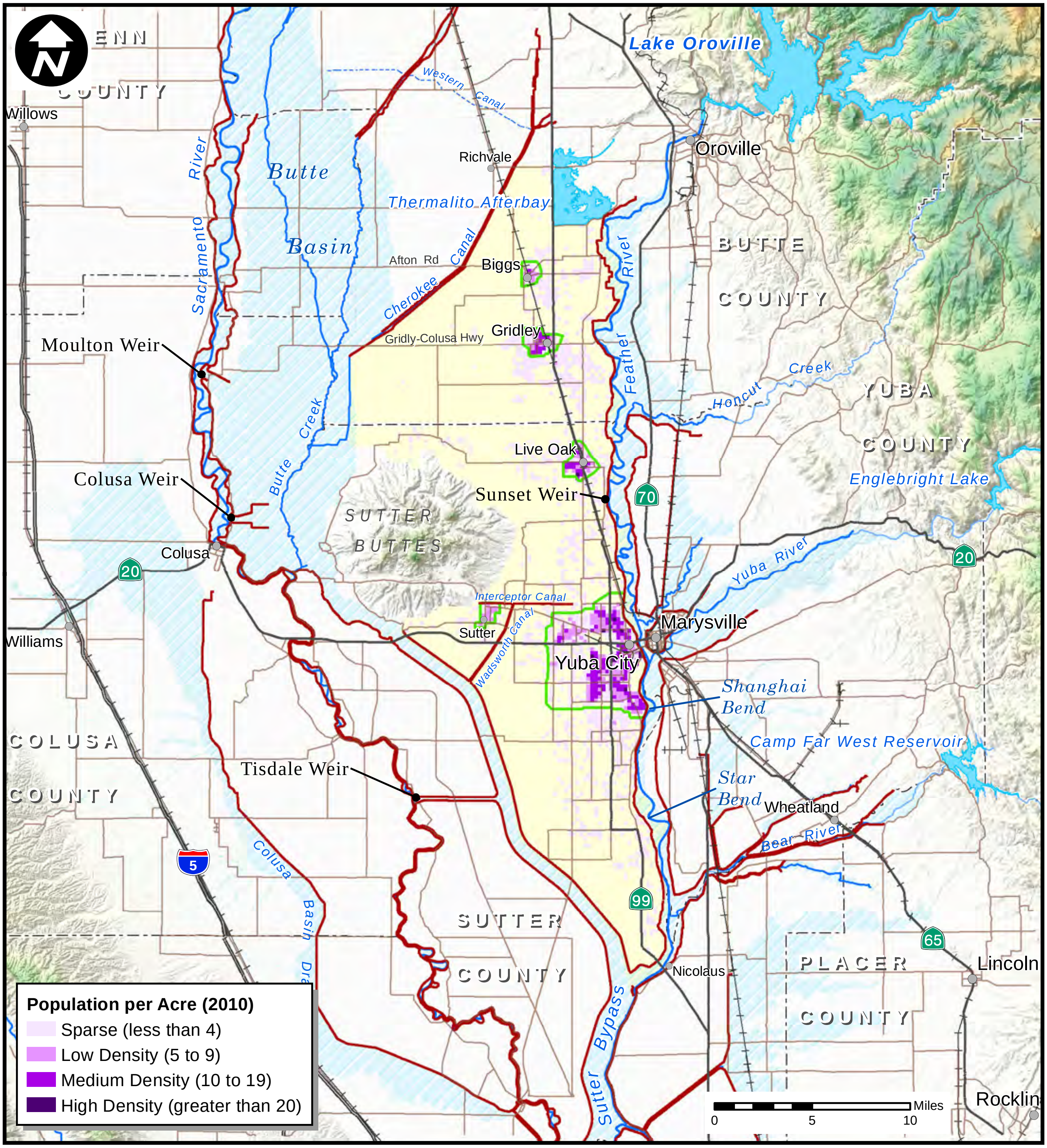
PLATE 3



Legend

Economic Evaluation Area

Study Area Extent

Designated Floodways

Lake or Reservoir

River or Stream

Federal Levee

Railroad

County Boundary

City or Town

SUTTER BASIN PILOT FEASIBILITY STUDY
SUTTER BASIN, CALIFORNIA

POPULATION DENSITY

U.S. ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT

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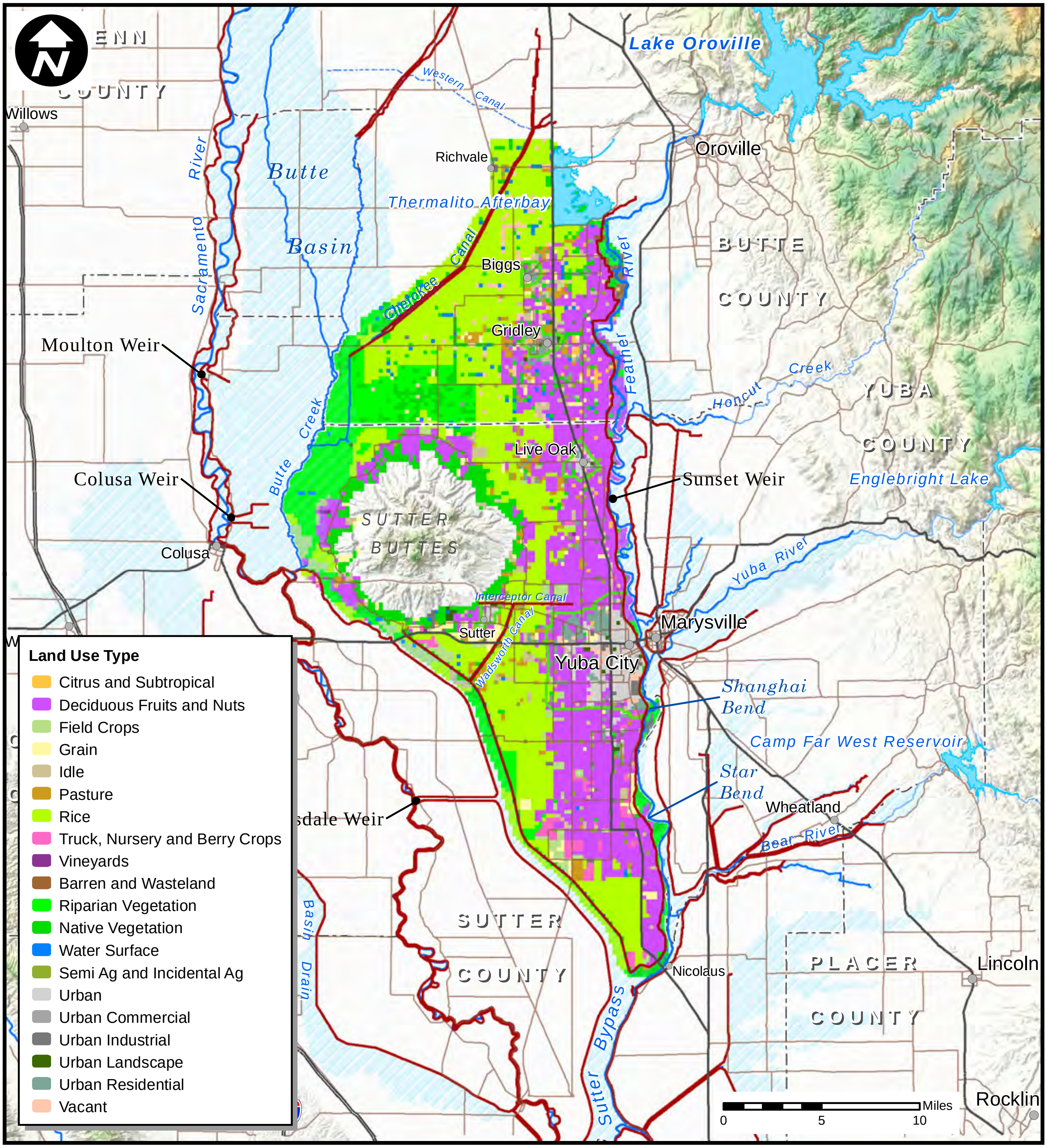
PLATE 4



Legend

Designated Floodways
Lake or Reservoir
River or Stream
Federal Levee
County Boundary
City or Town

SUTTER BASIN PILOT FEASIBILITY STUDY
SUTTER BASIN, CALIFORNIA

LAND USE

U.S. ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT

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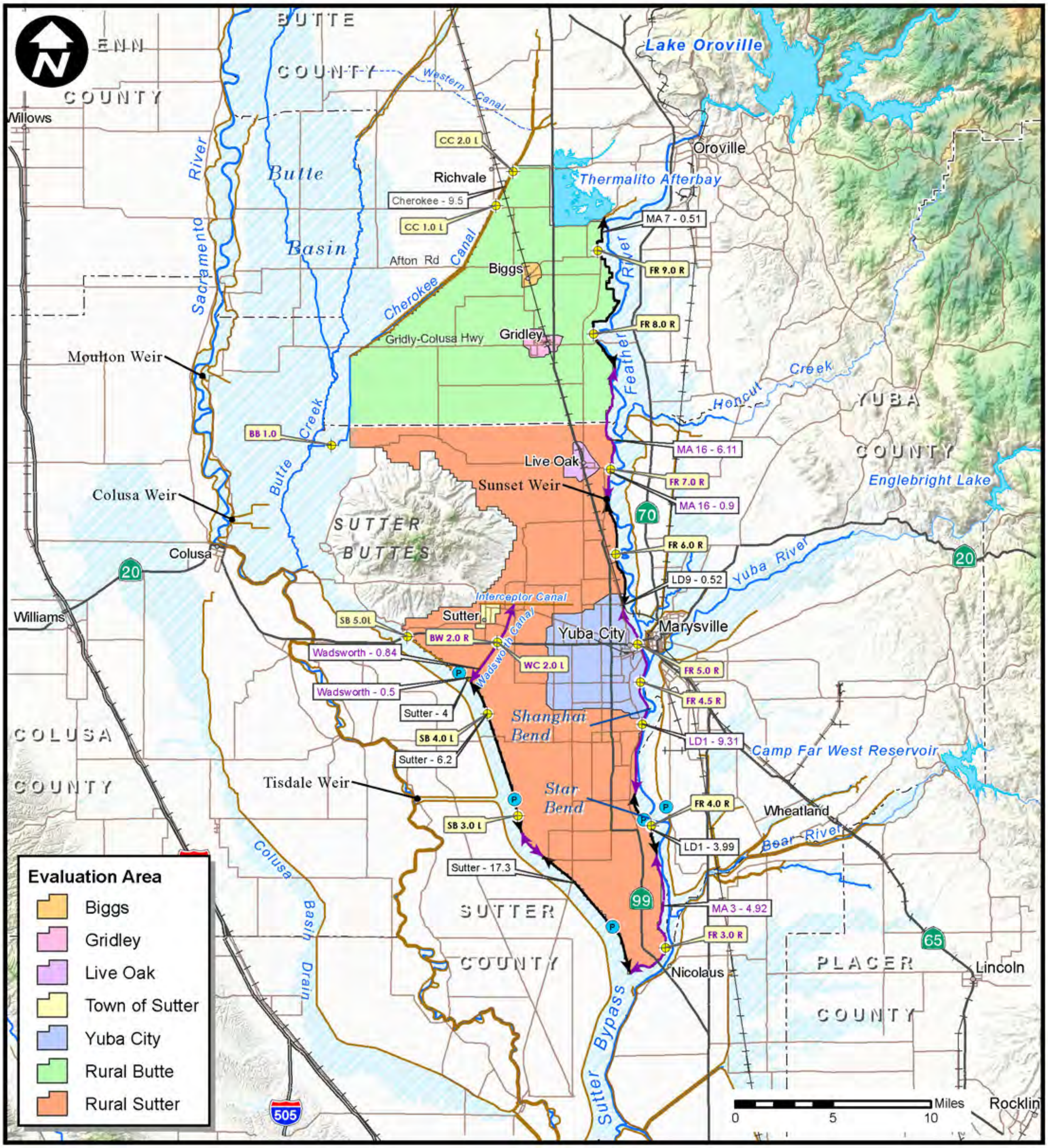

Legend

- Geotechnical Levee Reach
- Federal Levee
- Breach Simulation Site
- Geotechnical Index Point
- Pump Station
- City or Town
- Designated Floodways
- Lake or Reservoir
- River or Stream
- Railroad
- County Boundary

SUTTER BASIN PILOT FEASIBILITY STUDY
SUTTER BASIN, CALIFORNIA

ECONOMIC IMPACT AREAS

U.S. ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT

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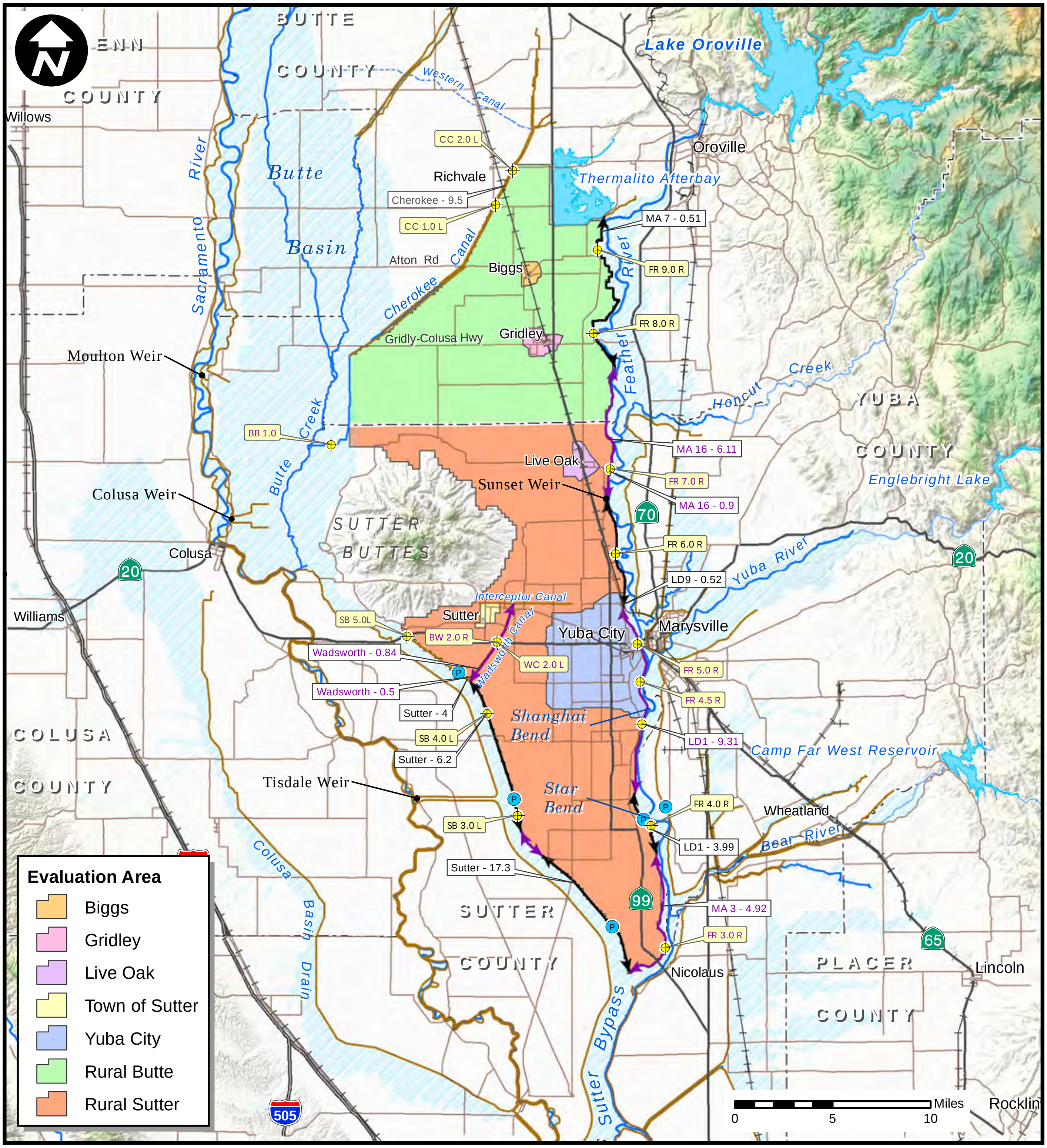
PLATE 6



Legend

- Geotechnical Levee Reach
- Federal Levee
- Breach Simulation Site
- Geotechnical Index Point
- Pump Station
- City or Town
- Designated Floodways
- Lake or Reservoir
- River or Stream
- Railroad
- County Boundary

SUTTER BASIN PILOT FEASIBILITY STUDY
SUTTER BASIN, CALIFORNIA

ECONOMIC IMPACT AREAS

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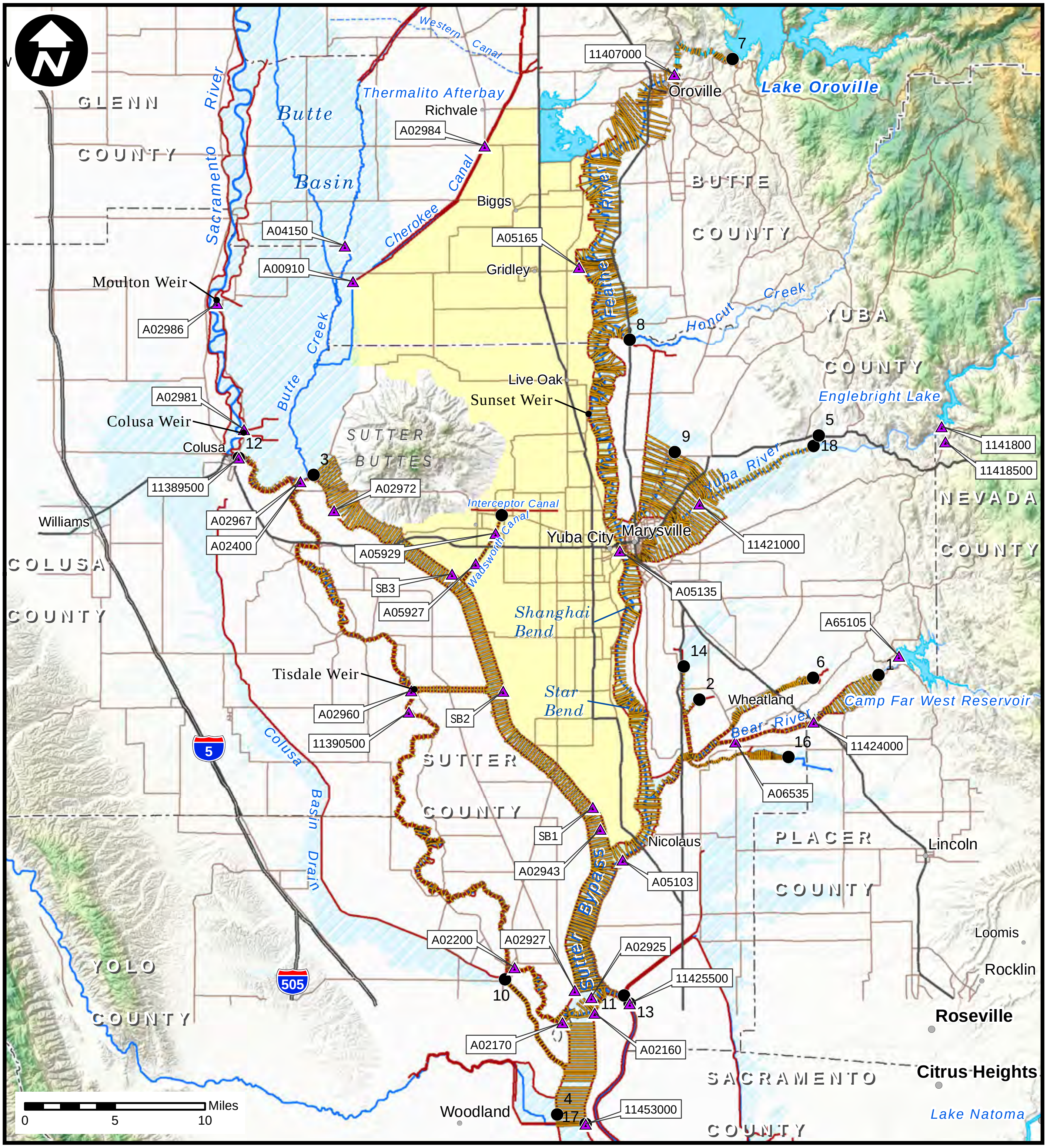

Legend

- Stream Gage
- Model Boundaries
- Model Cross Sectios
- Federal Levee
- Study Area Extent
- Designated Floodways

NOTE: See Table 1 and 2 for Model Boundary Name

SUTTER BASIN PILOT FEASIBILITY STUDY
SUTTER BASIN, CALIFORNIA

HEC-RAS HYDRAULIC MODEL BOUNDARY CONDITIONS AND STREAM GAGES

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SACRAMENTO DISTRICT

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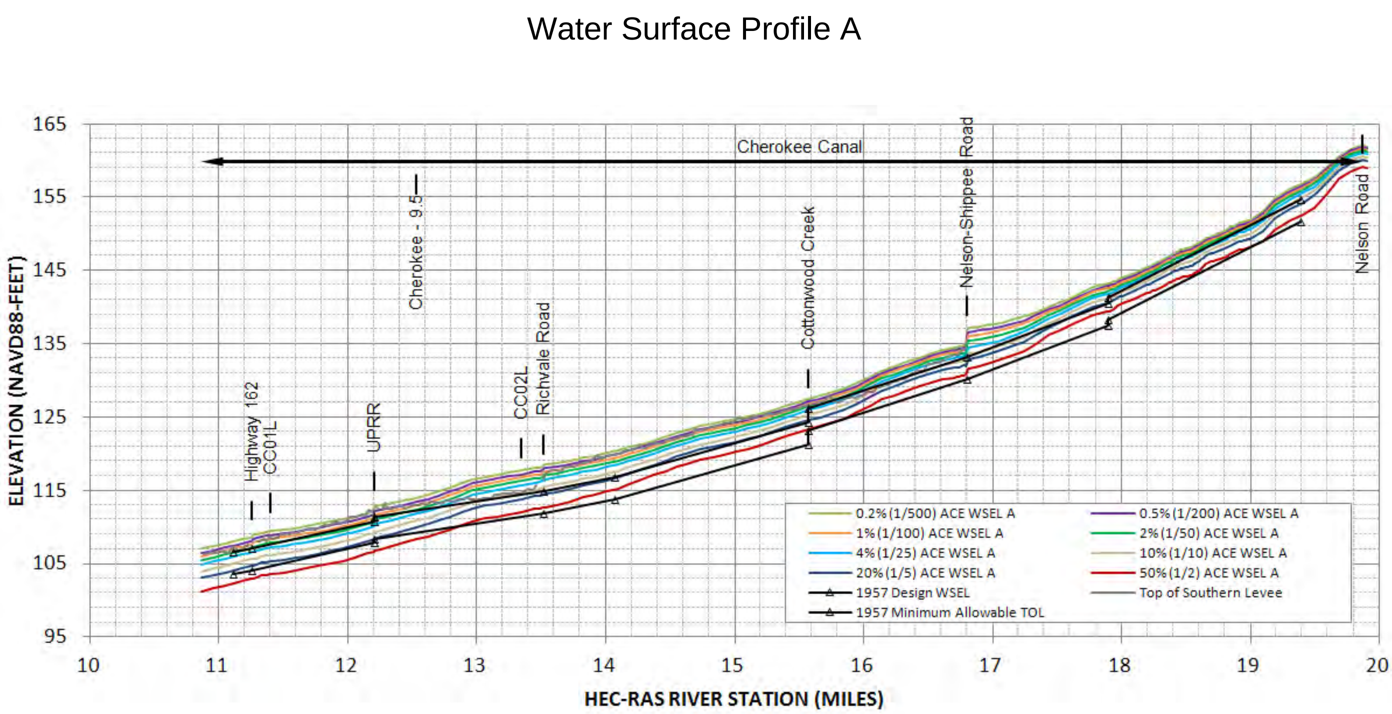
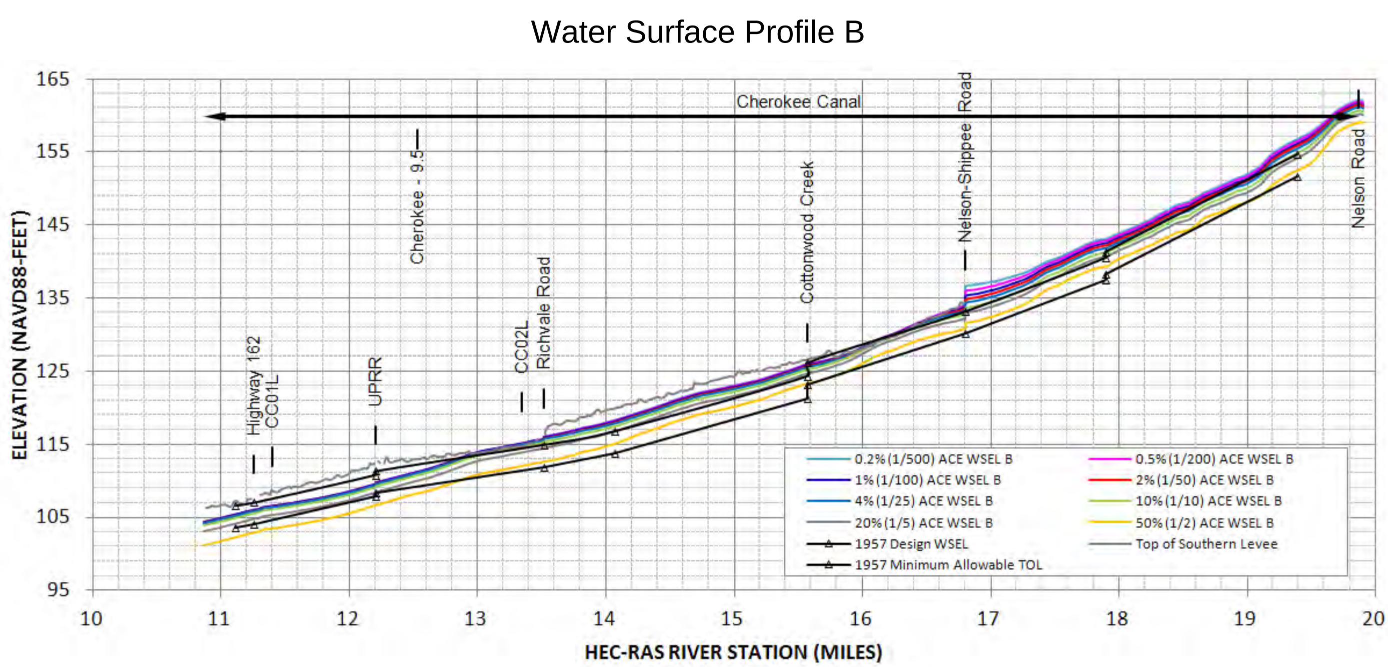
PLATE 7





Notes:

Water Surface Profile A assumes infinite levee height, no overtopping.

Water Surface Profile B assumes overtopping only, no failure.

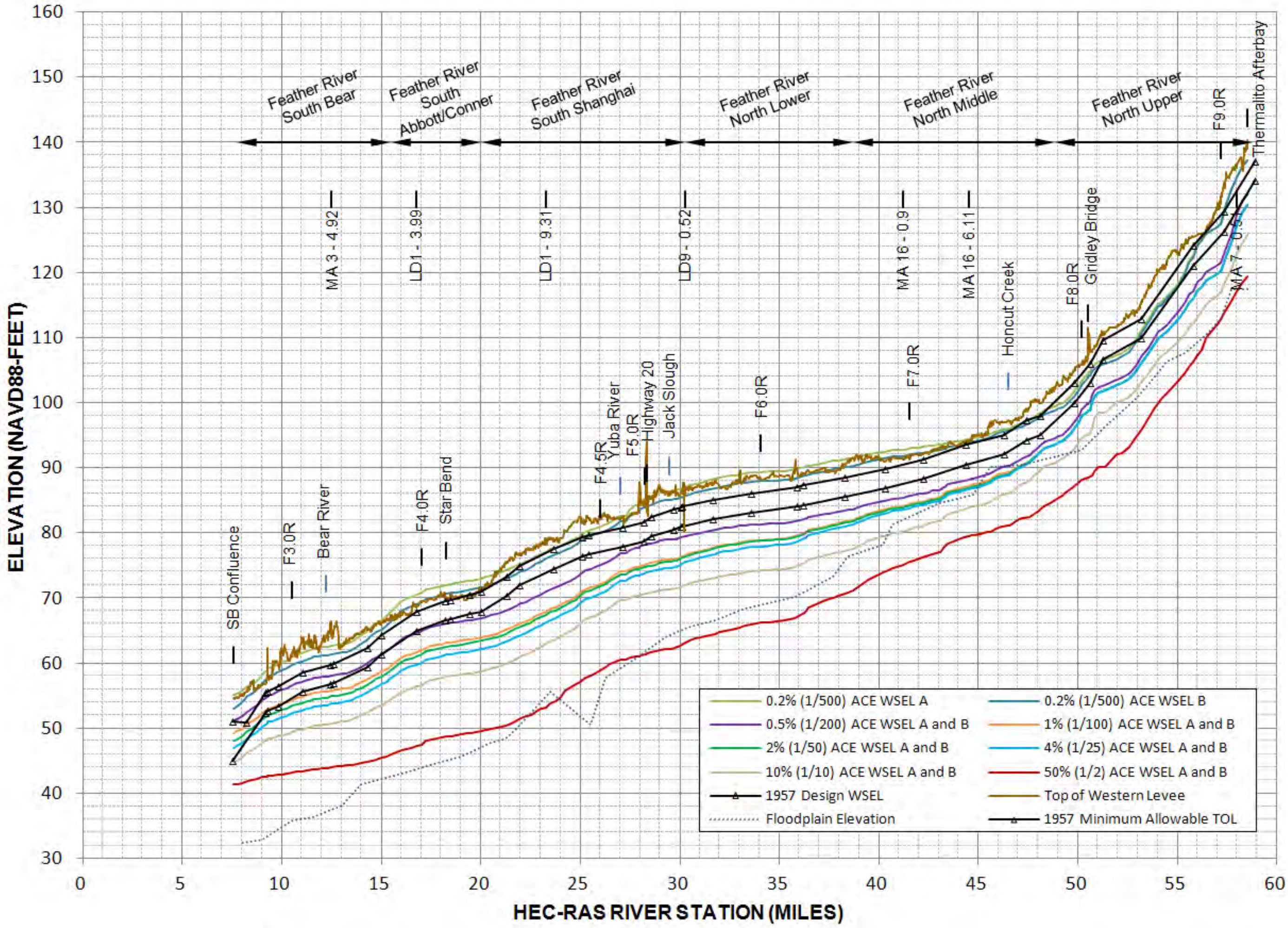
WSEL = Water Surface Elevation

Source:

SUTTER BASIN FEASBILITY STUDY
SUTTER BASIN, CALIFORNIA

CHEROKEE CANAL
WATER SURFACE PROFILES

U.S ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT



Notes:

Water Surface Profile A assumes infinite height levee, no overtopping.

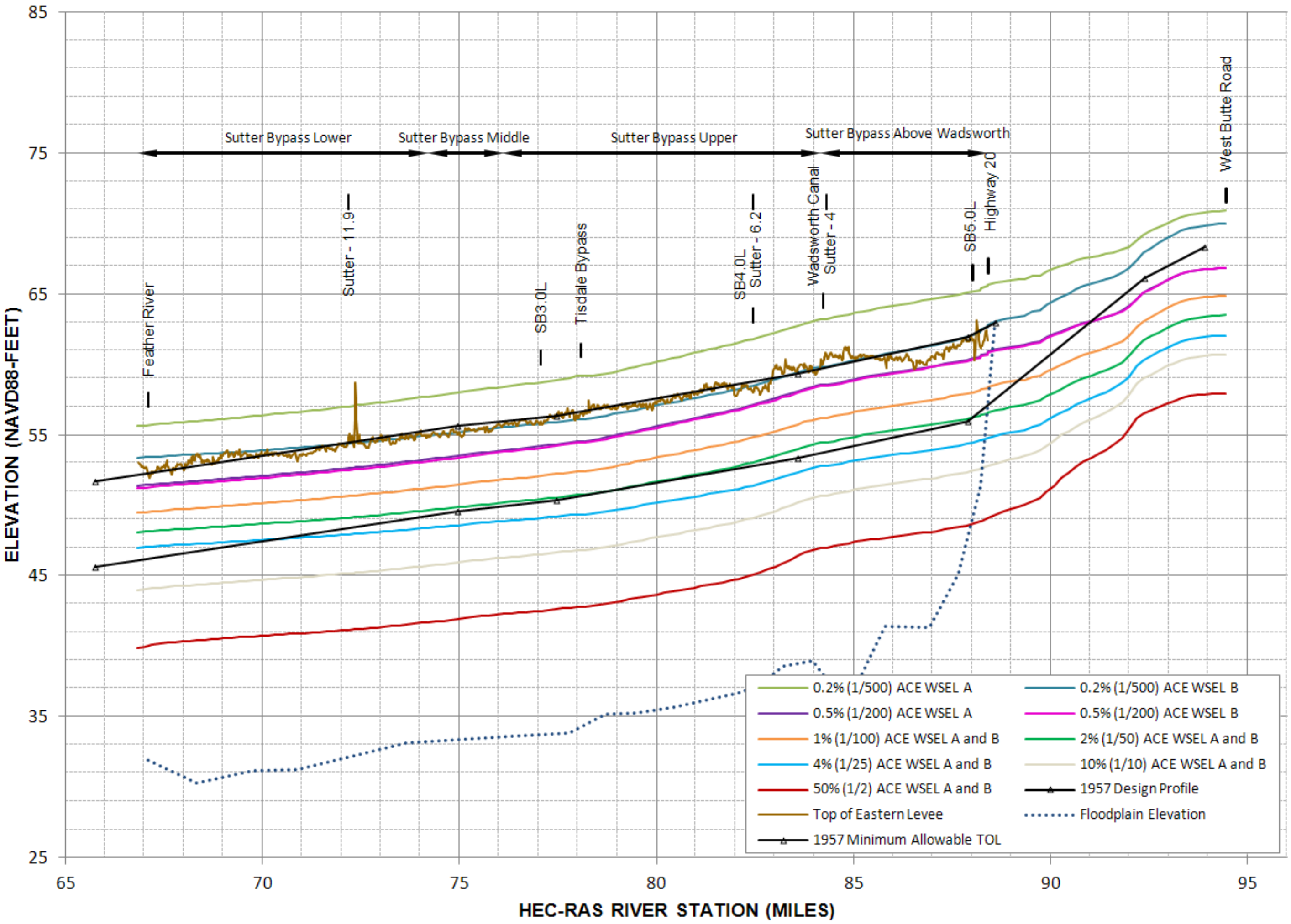
Water Surface Profile B assumes overtopping, no failure

WSEL = Water Surface Elevation

SUTTER BASIN FEASBILITY STUDY
SUTTER BASIN, CALIFORNIA

FEATHER RIVER WATER SURFACE PROFILES

U.S ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT



Note:

Water Surface Profile A assumes infinite levee height, no overtopping.

Water Surface Elevation B assumes overtopping only, no failure

WSEL = Water Surface Elevation

Source:

SUTTER BASIN FEASBILITY STUDY
SUTTER BASIN, CALIFORNIA

SUTTER BYPASS
WATER SURFACE PROFILES

U.S ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT

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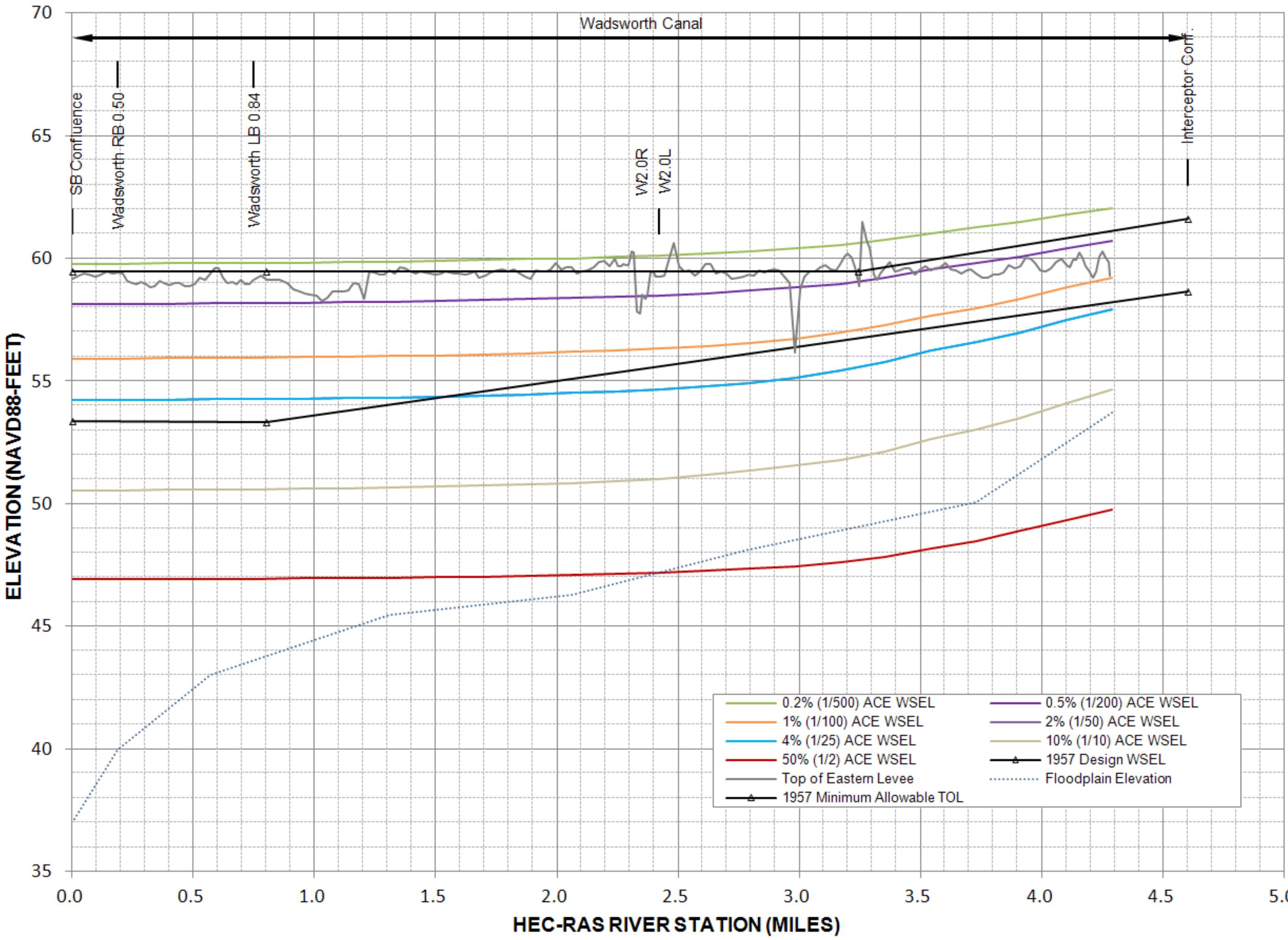
PLATE 10



Notes:

Water Surface Profiles assume infinite height levee, no overtopping.

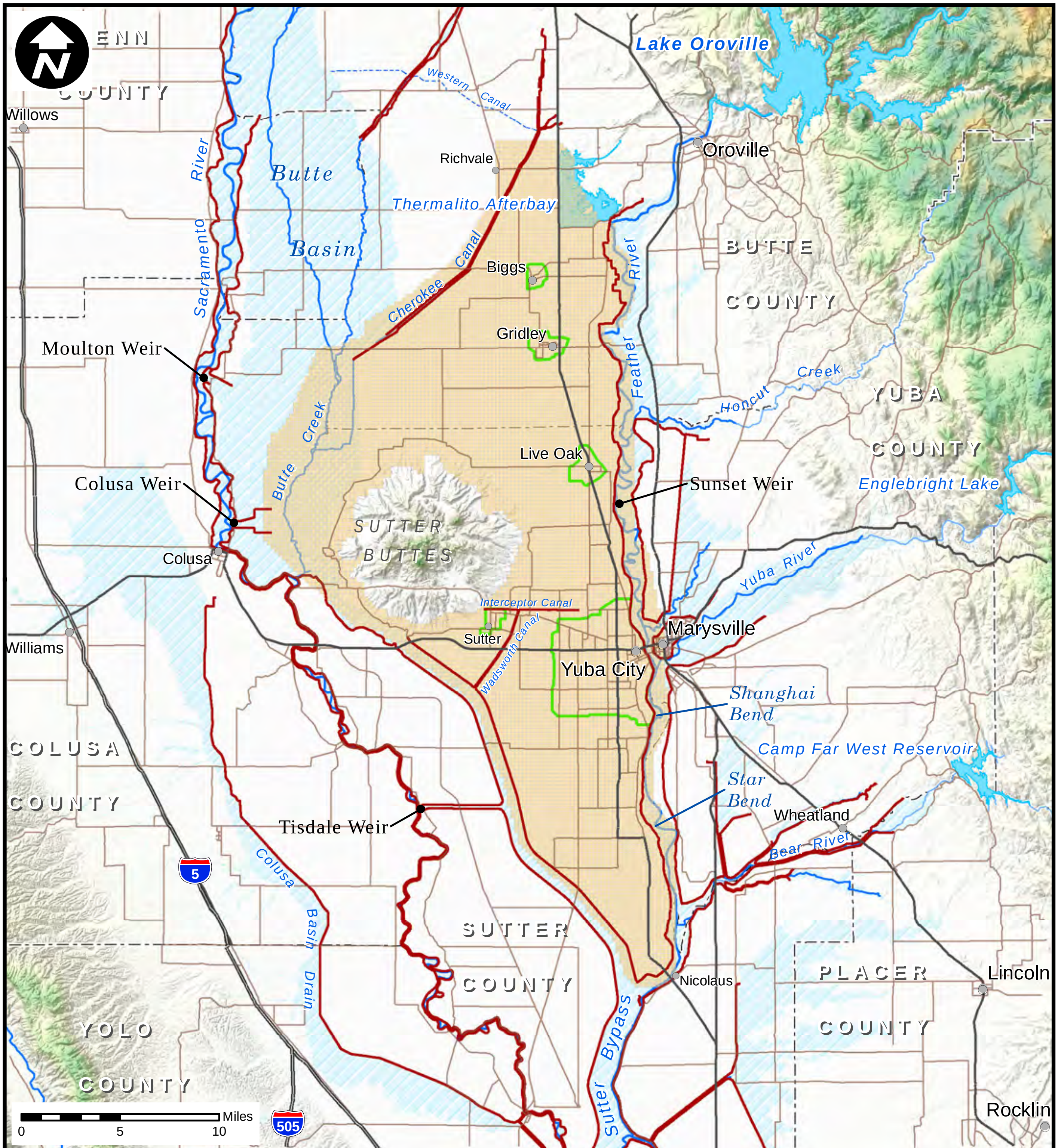
Overtopping, no failure was not created for Wadsworth Canal.

WSEL = Water Surface Elevation

SUTTER BASIN FEASBILITY STUDY
SUTTER BASIN, CALIFORNIA

WADSWORTH CANAL WATER SURFACE PROFILES

U.S ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT



Legend

- FLO2D Grid
- Designated Floodways
- Lake or Reservoir
- Economic Evaluation Area
- River or Stream
- Federal Levee
- County Boundary
- City or Town

SUTTER BASIN PILOT FEASIBILITY STUDY
SUTTER BASIN, CALIFORNIA

FLO2D MODEL GRID

U.S. ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT

Prepared by Jim Mars

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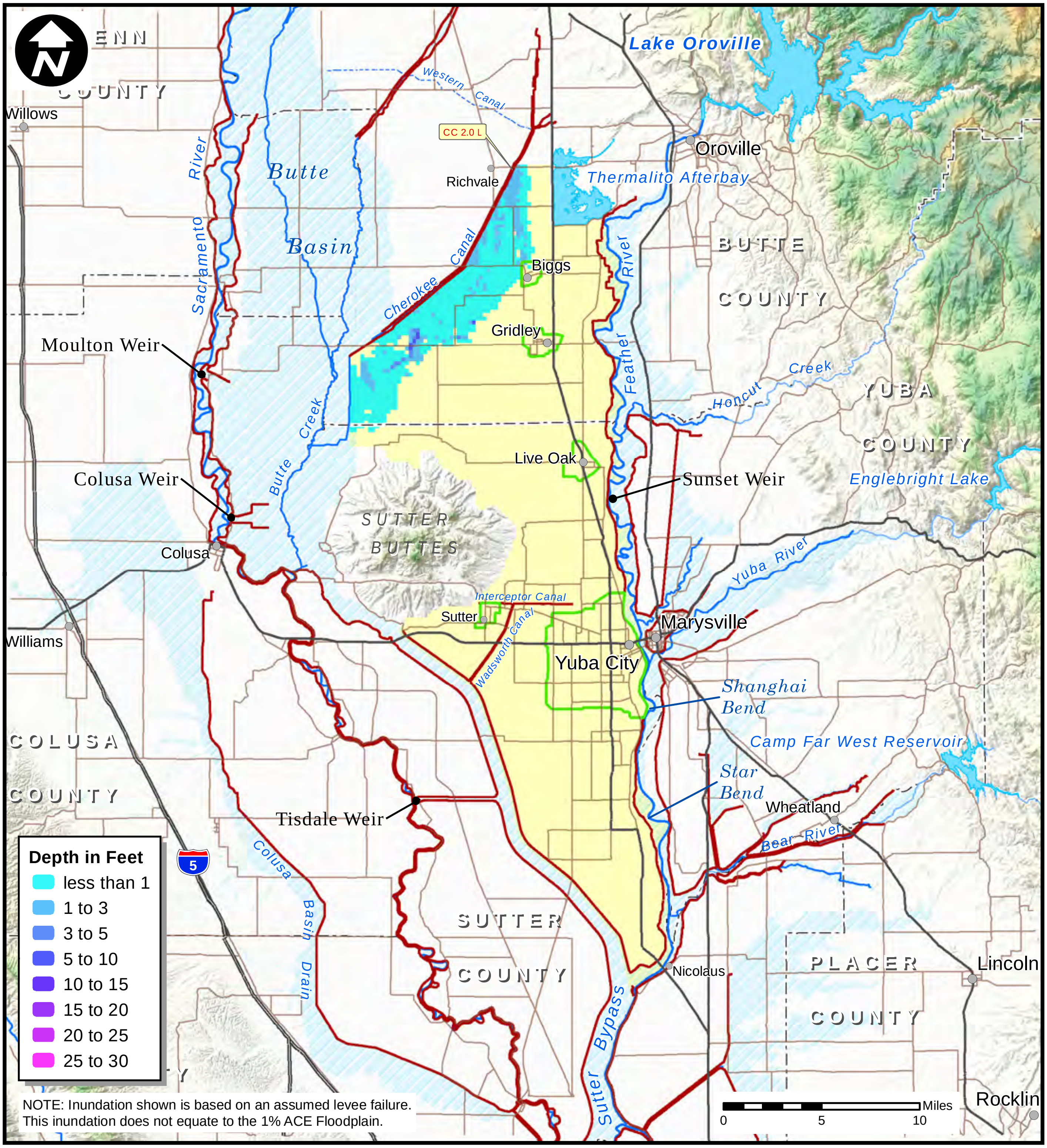
PLATE 12



Legend

- Breach Index Point
- Designated Floodways
- Lake or Reservoir
- River or Stream
- Study Area Extent
- Federal Levee
- County Boundary
- City or Town

SUTTER BASIN PILOT FEASIBILITY STUDY
SUTTER BASIN, CALIFORNIA

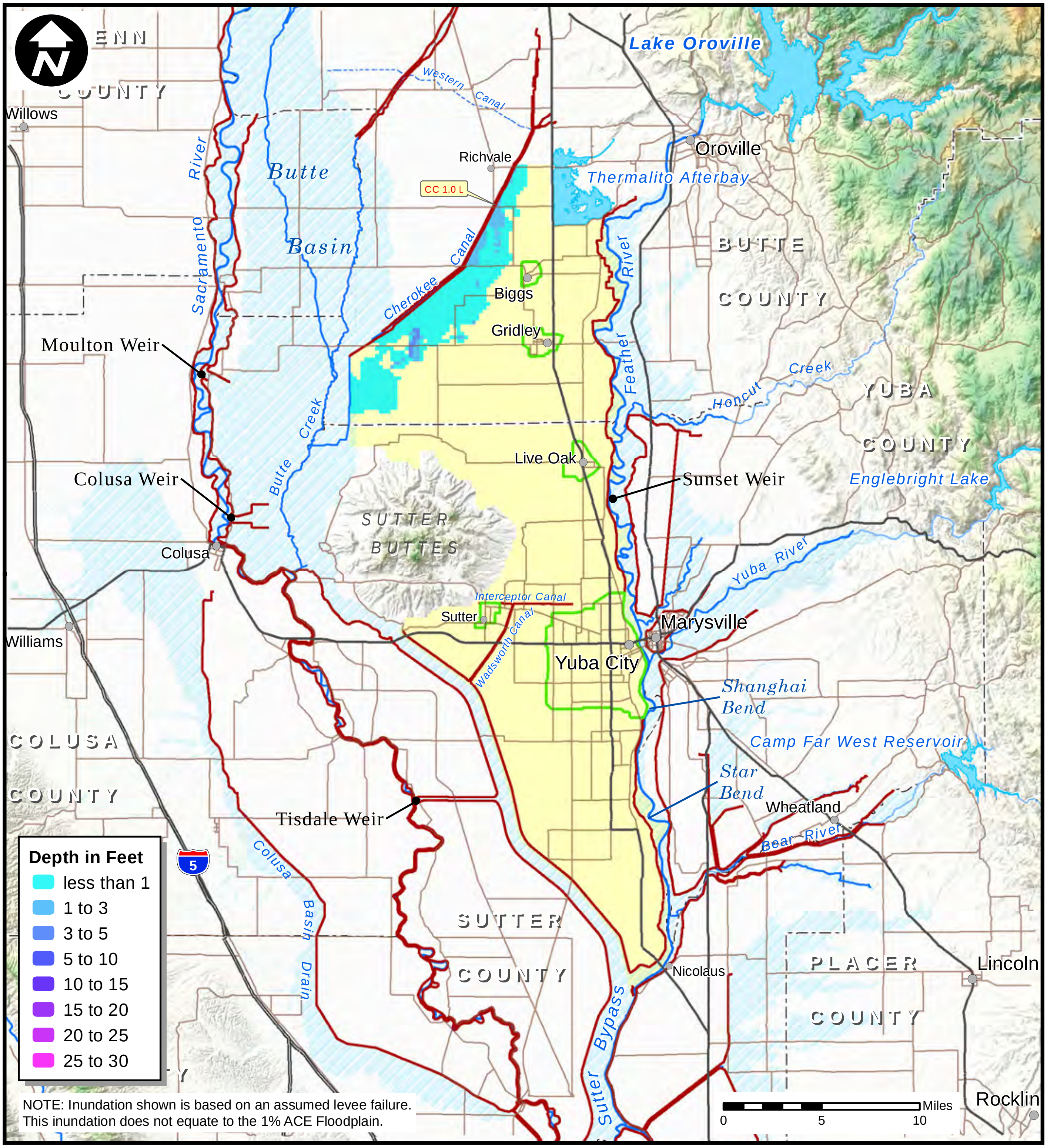
MODELED BREACH INUNDATION
CC 2.0 L INDEX POINT
1% ACE EVENT

U.S. ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT

Prepared by Jim Mars

OCT 2012

PLATE 13



Legend

Breach Index Point	Study Area Extent
Designated Floodways	Federal Levee
Lake or Reservoir	County Boundary
River or Stream	City or Town

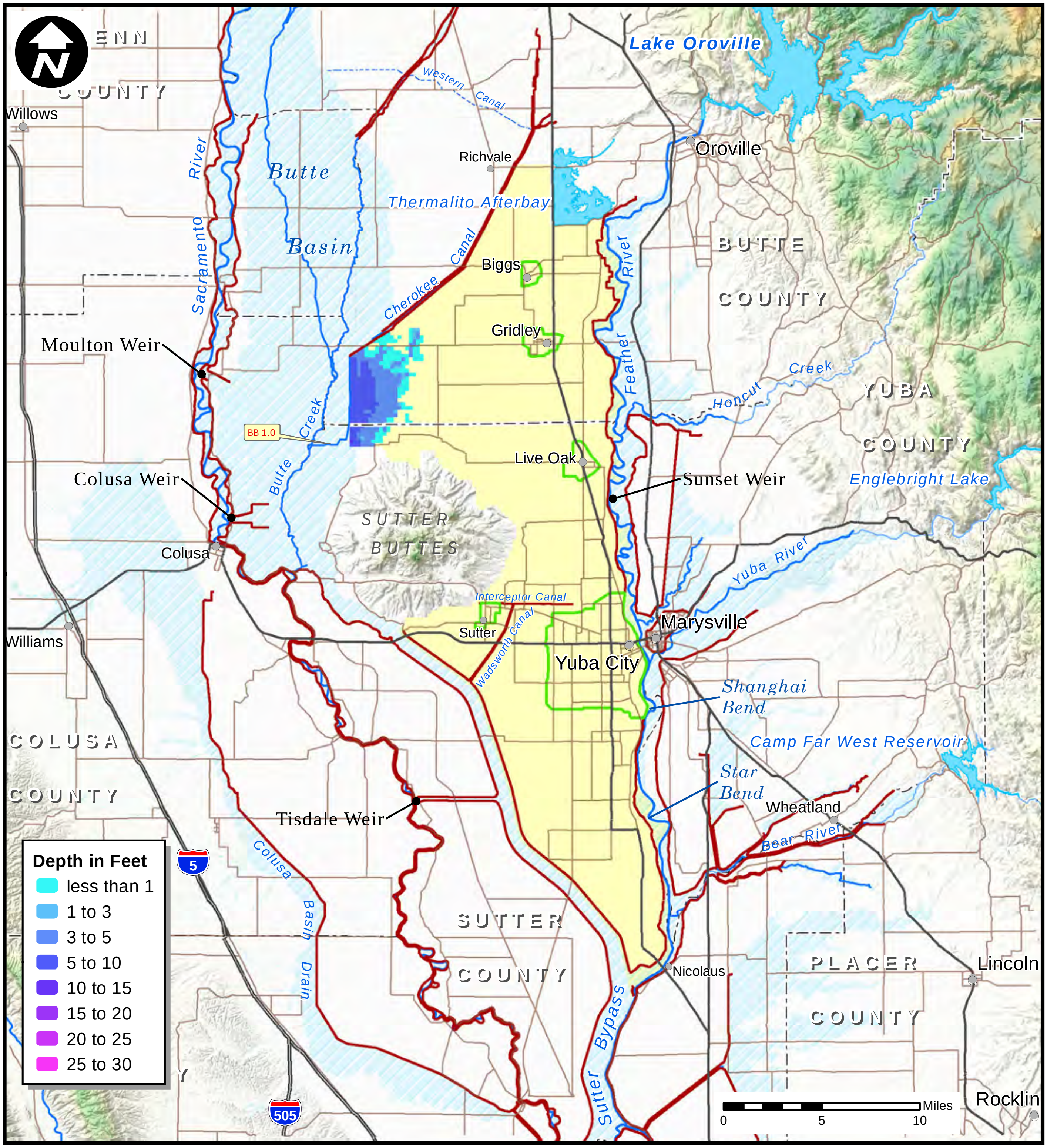
SUTTER BASIN PILOT FEASIBILITY STUDY
SUTTER BASIN, CALIFORNIA

MODELED BREACH INUNDATION
CC 1.0 L INDEX POINT
1% ACE EVENT

U.S. ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT

Prepared by Jim Mars

OCT 2012



Legend

Flood Source Point	Study Area Extent
Designated Floodways	Federal Levee
Lake or Reservoir	County Boundary
River or Stream	City or Town

SUTTER BASIN PILOT FEASIBILITY STUDY
SUTTER BASIN, CALIFORNIA

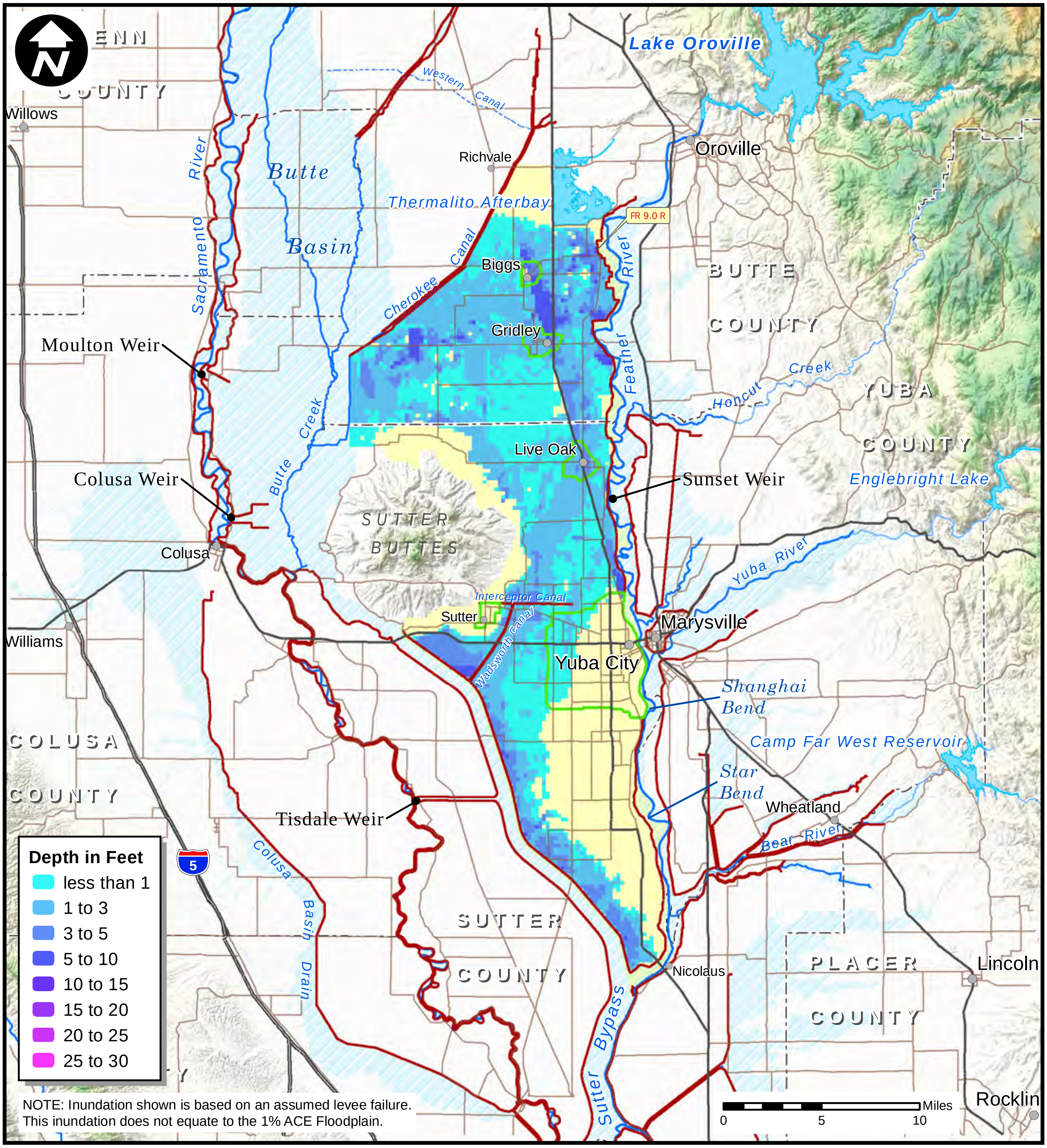
MODELED INUNDATION
BB 1.0 INDEX POINT
1% ACE EVENT

U.S. ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT

Prepared by Jim Mars

OCT 2012

PLATE 15



Legend

- Breach Index Point
- Designated Floodways
- Lake or Reservoir
- River or Stream
- Study Area Extent
- Federal Levee
- County Boundary
- City or Town

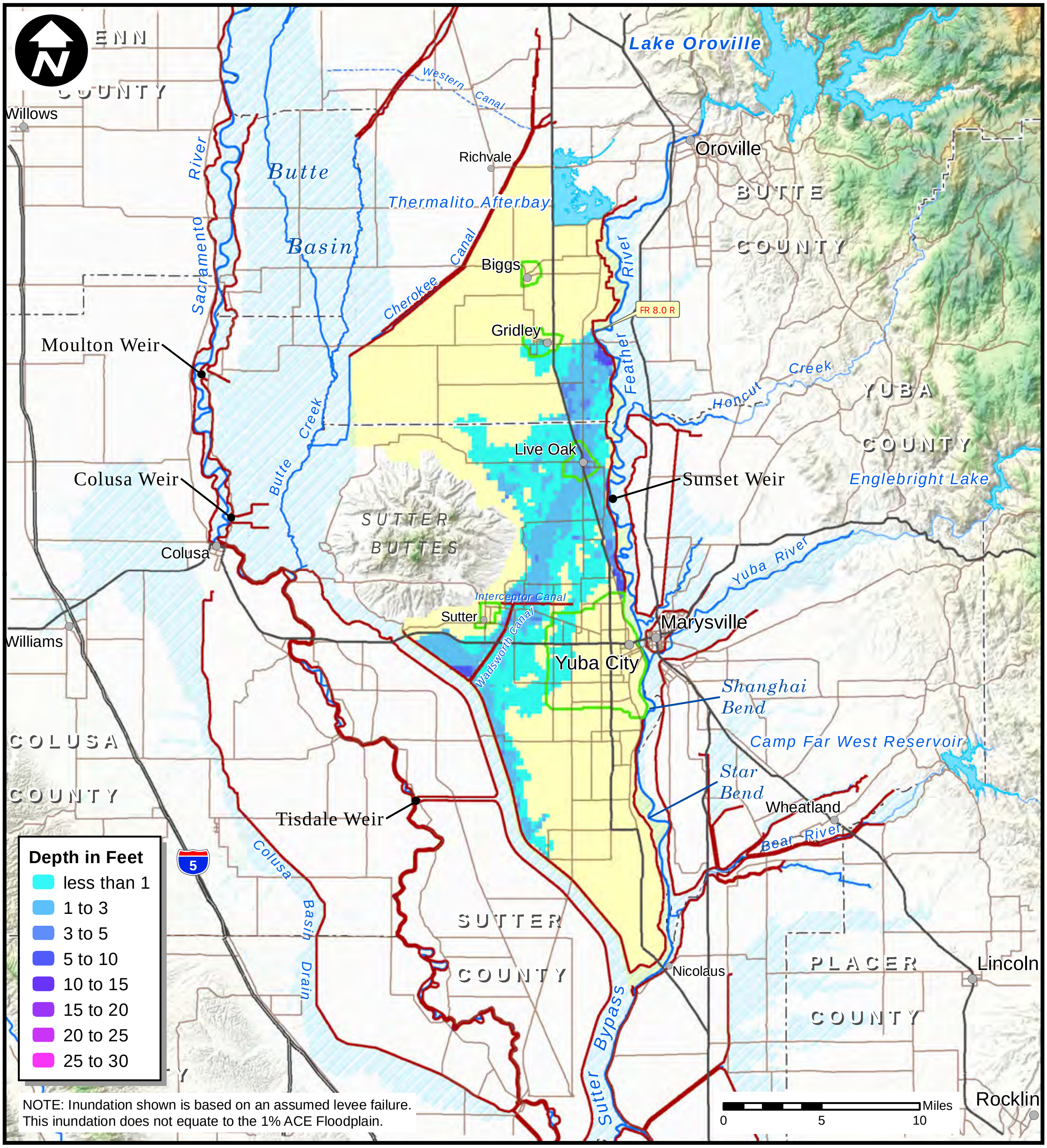
SUTTER BASIN PILOT FEASIBILITY STUDY
SUTTER BASIN, CALIFORNIA

MODELED BREACH INUNDATION
FR 9.0 R INDEX POINT
1% ACE EVENT

U.S. ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT

Prepared by Jim Mars

OCT 2012



Legend

- Breach Index Point
- Designated Floodways
- Lake or Reservoir
- River or Stream
- Study Area Extent
- Federal Levee
- County Boundary
- City or Town

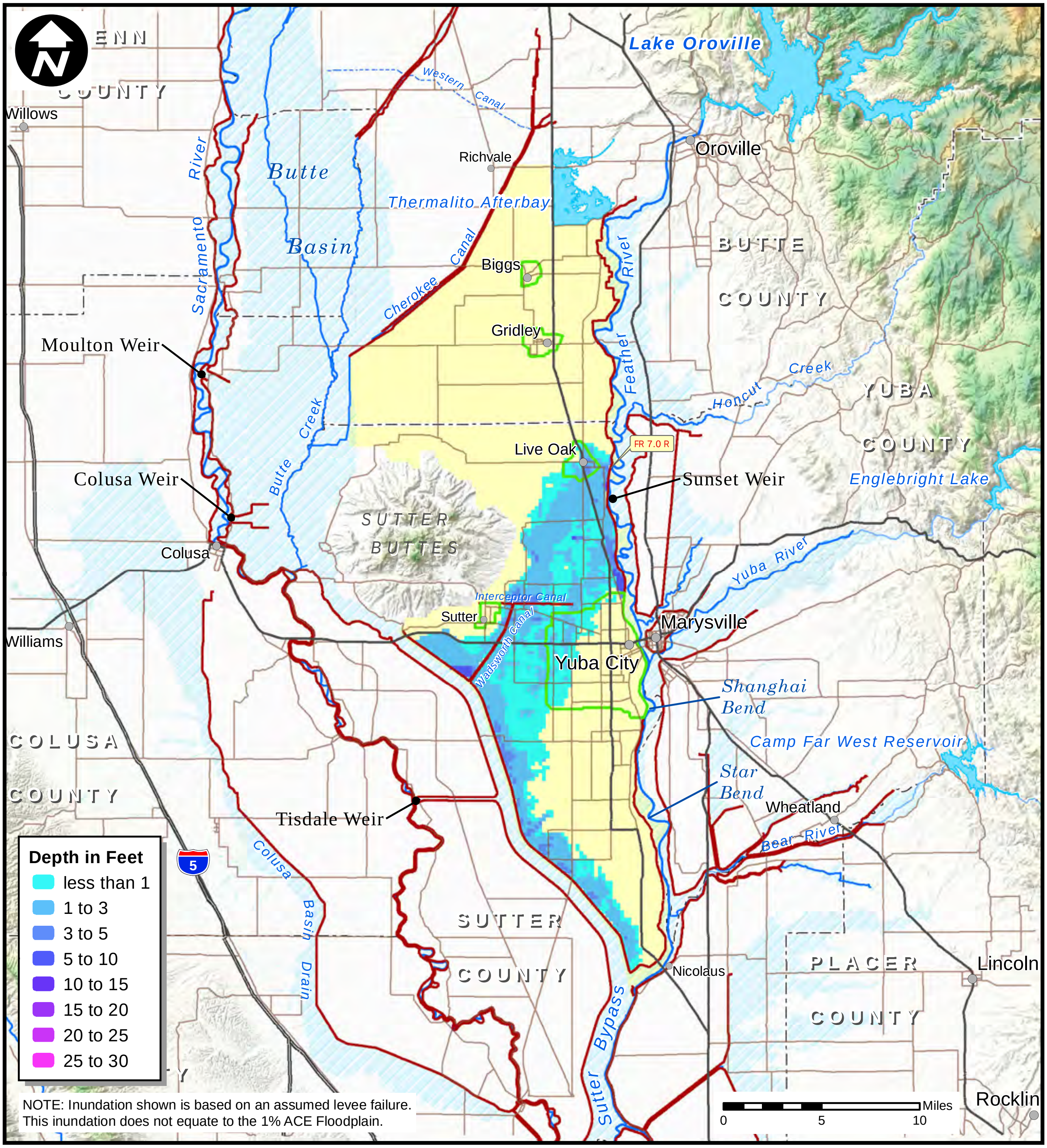
SUTTER BASIN PILOT FEASIBILITY STUDY
SUTTER BASIN, CALIFORNIA

MODELED BREACH INUNDATION
FR 8.0 R INDEX POINT
1% ACE EVENT

U.S. ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT

Prepared by Jim Mars

OCT 2012



Legend

Breach Index Point	Study Area Extent
Designated Floodways	Federal Levee
Lake or Reservoir	County Boundary
River or Stream	City or Town

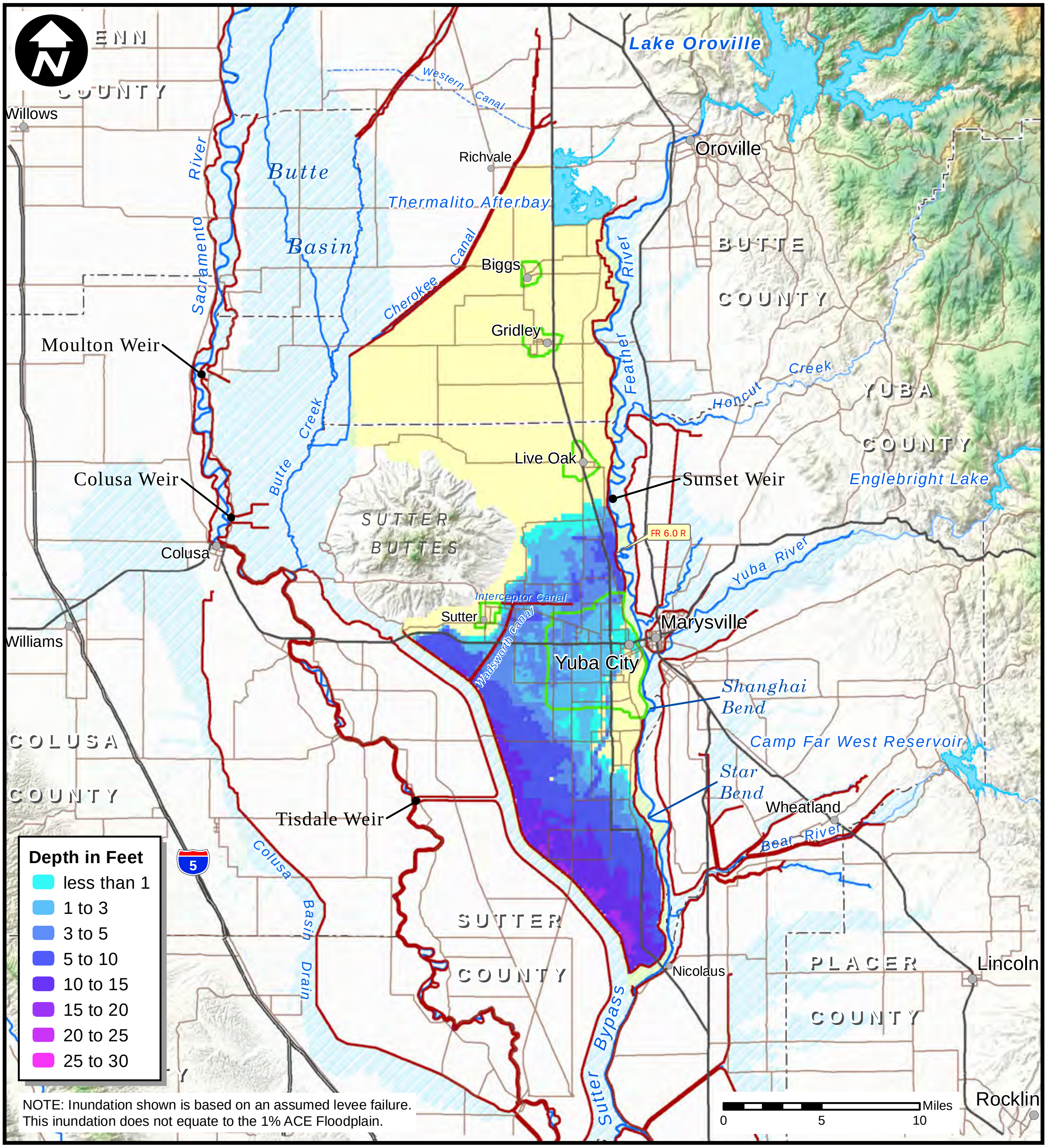
SUTTER BASIN PILOT FEASIBILITY STUDY
SUTTER BASIN, CALIFORNIA

MODELED BREACH INUNDATION FR 7.0 R INDEX POINT 1% ACE EVENT

U.S. ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT

Prepared by Jim Mars

OCT 2012



Legend

Breach Index Point
Study Area Extent
Designated Floodways
Federal Levee
Lake or Reservoir
County Boundary
River or Stream
City or Town

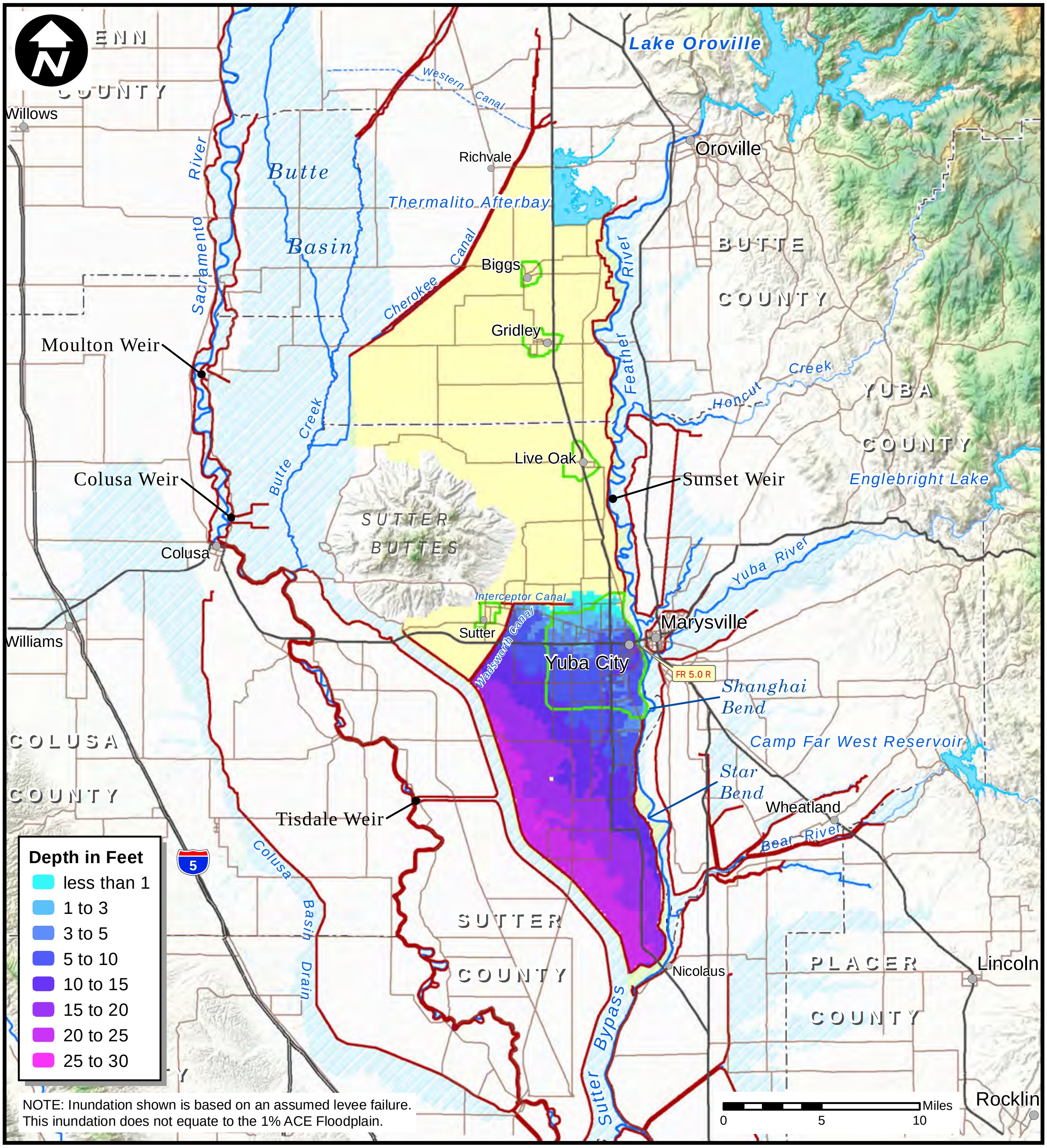
SUTTER BASIN PILOT FEASIBILITY STUDY
SUTTER BASIN, CALIFORNIA

MODELED BREACH INUNDATION
FR 6.0 R INDEX POINT
1% ACE EVENT

U.S. ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT

Prepared by Jim Mars

OCT 2012



Legend

- Breach Index Point
- Study Area Extent
- Designated Floodways
- Federal Levee
- Lake or Reservoir
- County Boundary
- River or Stream
- City or Town

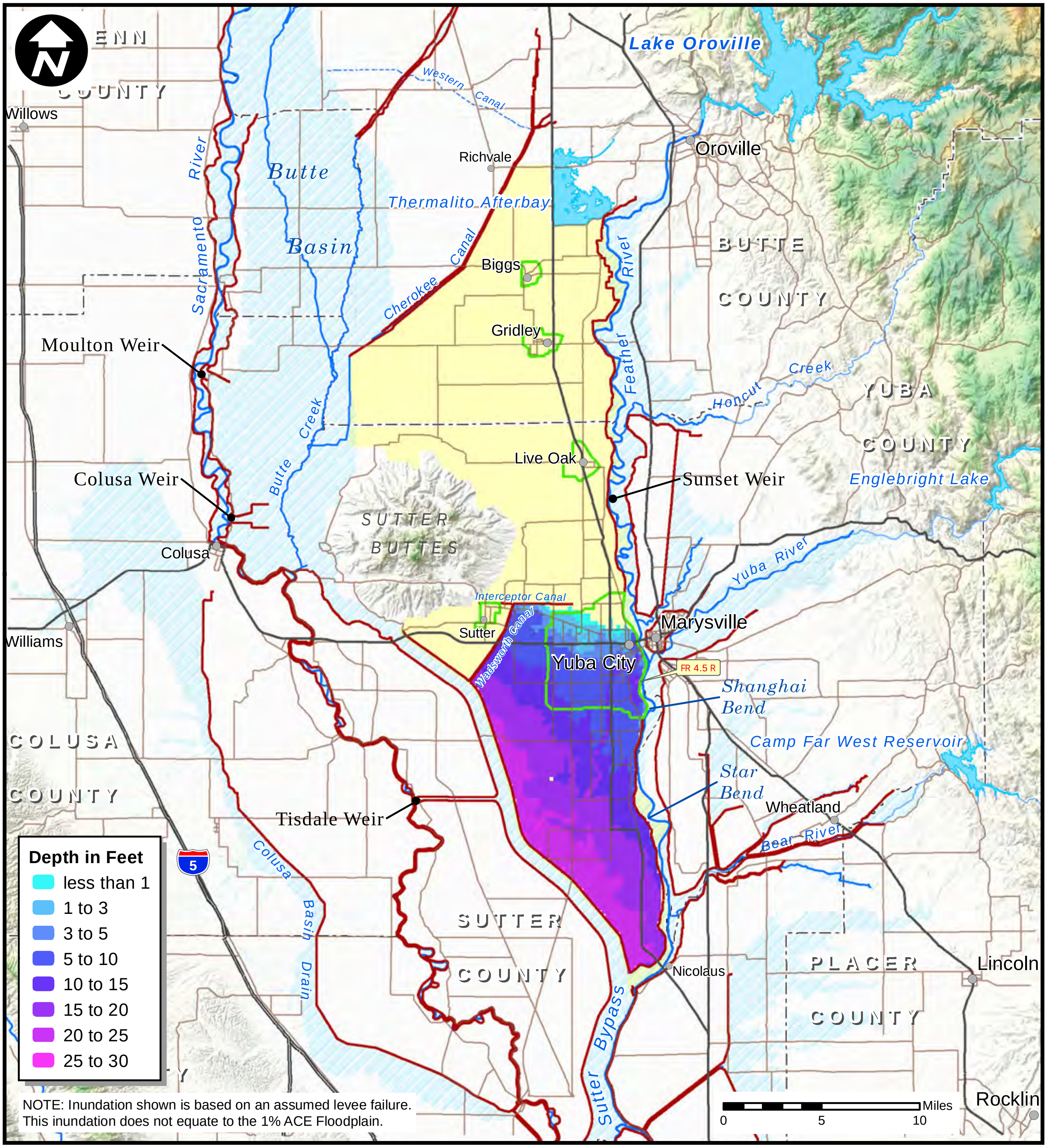
SUTTER BASIN PILOT FEASIBILITY STUDY
SUTTER BASIN, CALIFORNIA

MODELED BREACH INUNDATION FR 5.0 R INDEX POINT 1% ACE EVENT

U.S. ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT

Prepared by Jim Mars

OCT 2012



Legend

Breach Index Point	Study Area Extent
Designated Floodways	Federal Levee
Lake or Reservoir	County Boundary
River or Stream	City or Town

SUTTER BASIN PILOT FEASIBILITY STUDY
SUTTER BASIN, CALIFORNIA

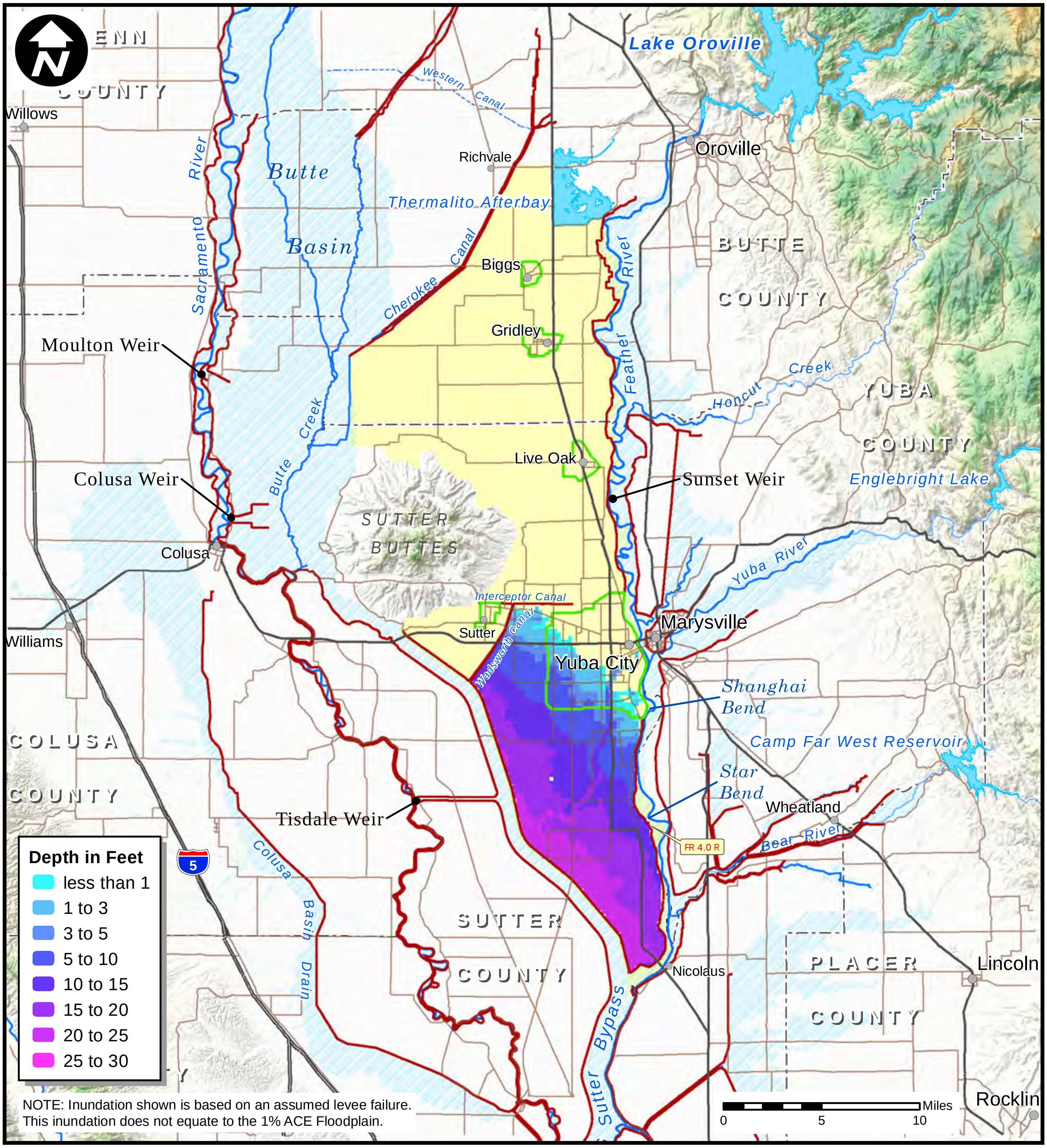
MODELED BREACH INUNDATION
FR 4.5 R INDEX POINT
1% ACE EVENT

U.S. ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT

Prepared by Jim Mars

OCT 2012

PLATE 21



Legend

- Breach Index Point
- Designated Floodways
- Lake or Reservoir
- River or Stream
- Study Area Extent
- Federal Levee
- County Boundary
- City or Town

SUTTER BASIN PILOT FEASIBILITY STUDY
SUTTER BASIN, CALIFORNIA

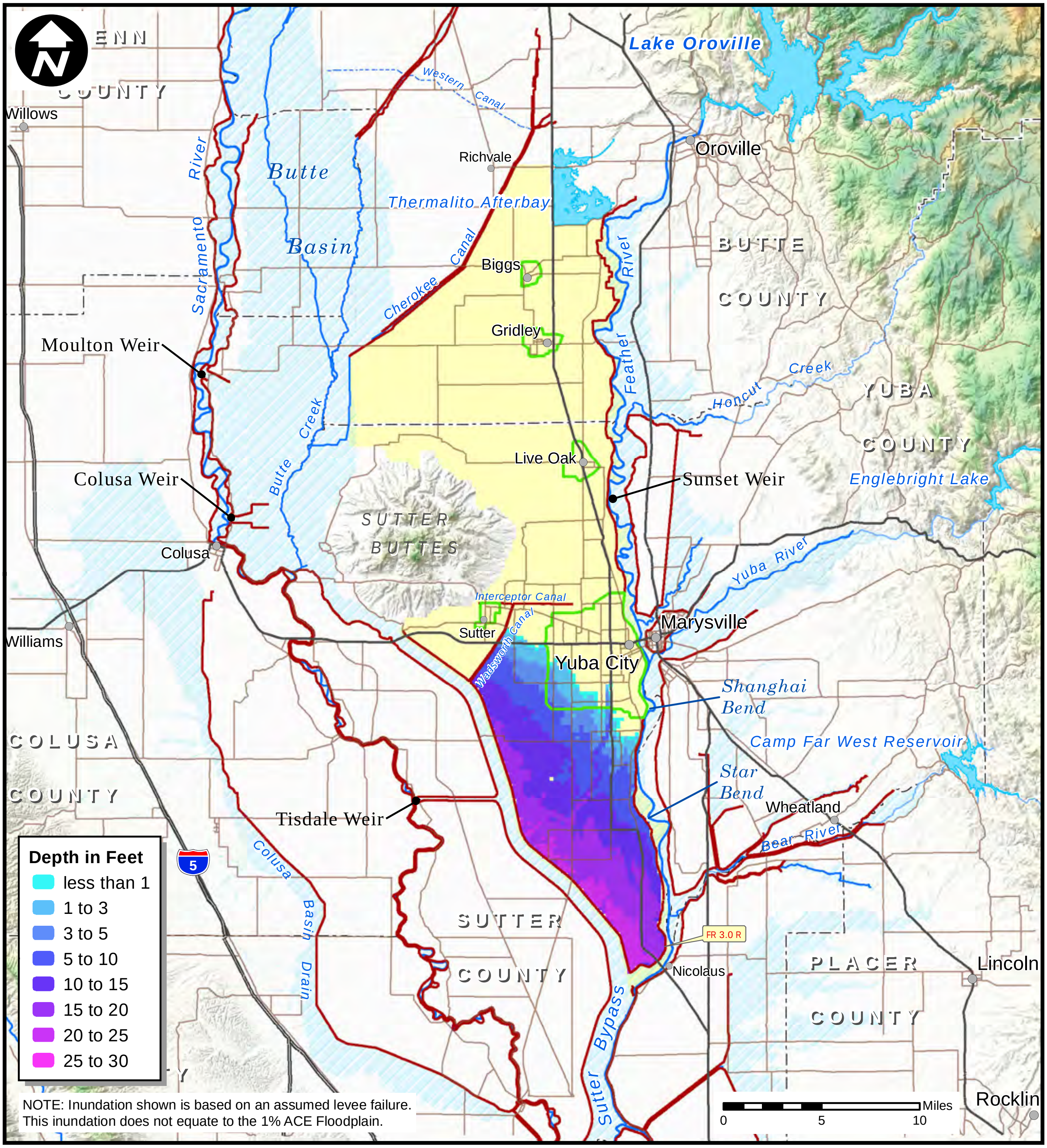
MODELED BREACH INUNDATION
FR 4.0 R INDEX POINT
1% ACE EVENT

U.S. ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT

Prepared by Jim Mars

OCT 2012

PLATE 22



Legend

Breach Index Point	Study Area Extent
Designated Floodways	Federal Levee
Lake or Reservoir	County Boundary
River or Stream	City or Town

SUTTER BASIN PILOT FEASIBILITY STUDY
SUTTER BASIN, CALIFORNIA

MODELED BREACH INUNDATION
FR 3.0 R INDEX POINT
1% ACE EVENT

U.S. ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT

Prepared by Jim Mars

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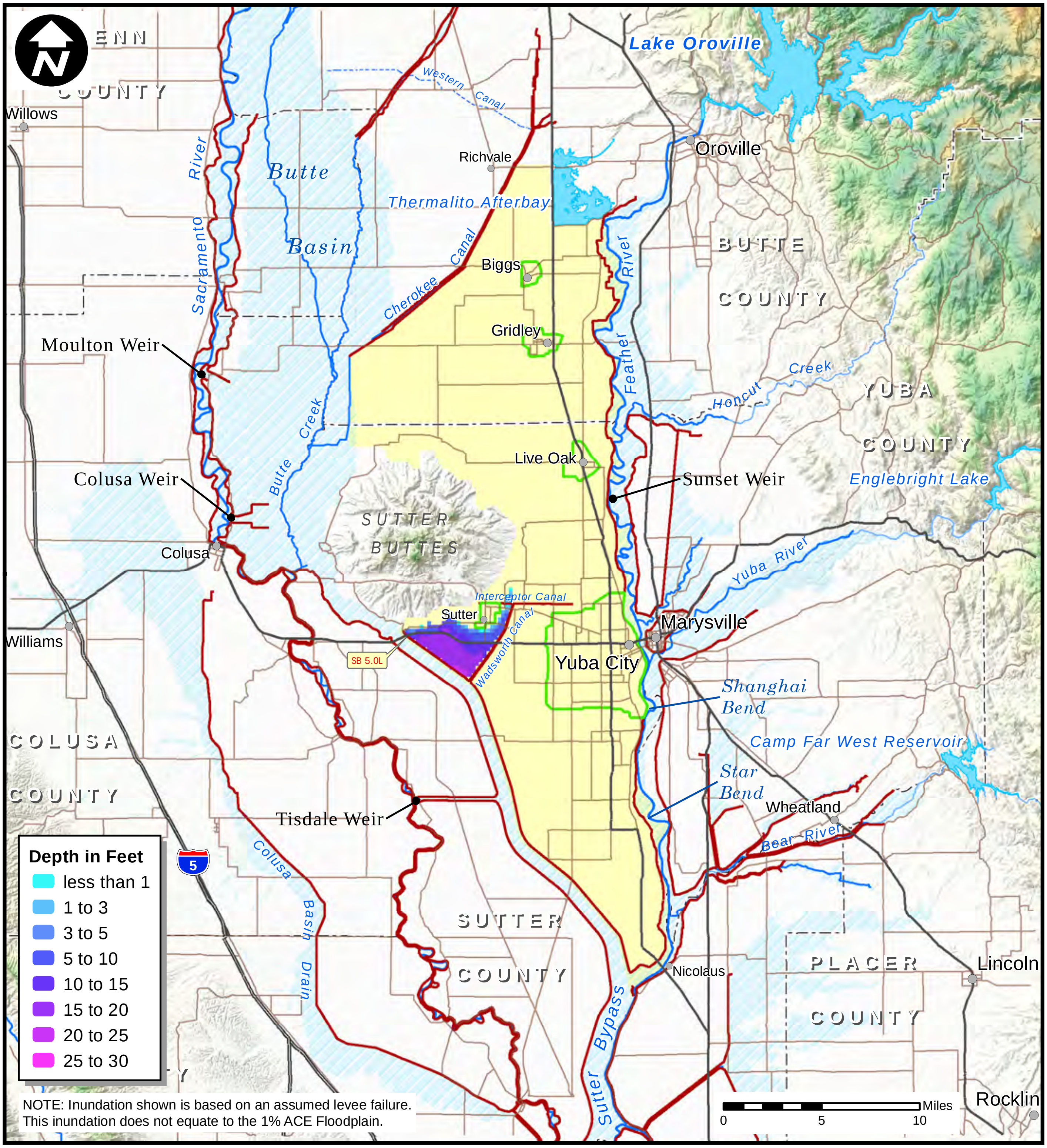


Legend

- Breach Index Point
- Study Area Extent
- Designated Floodways
- Federal Levee
- Lake or Reservoir
- County Boundary
- River or Stream
- City or Town

SUTTER BASIN PILOT FEASIBILITY STUDY
SUTTER BASIN, CALIFORNIA

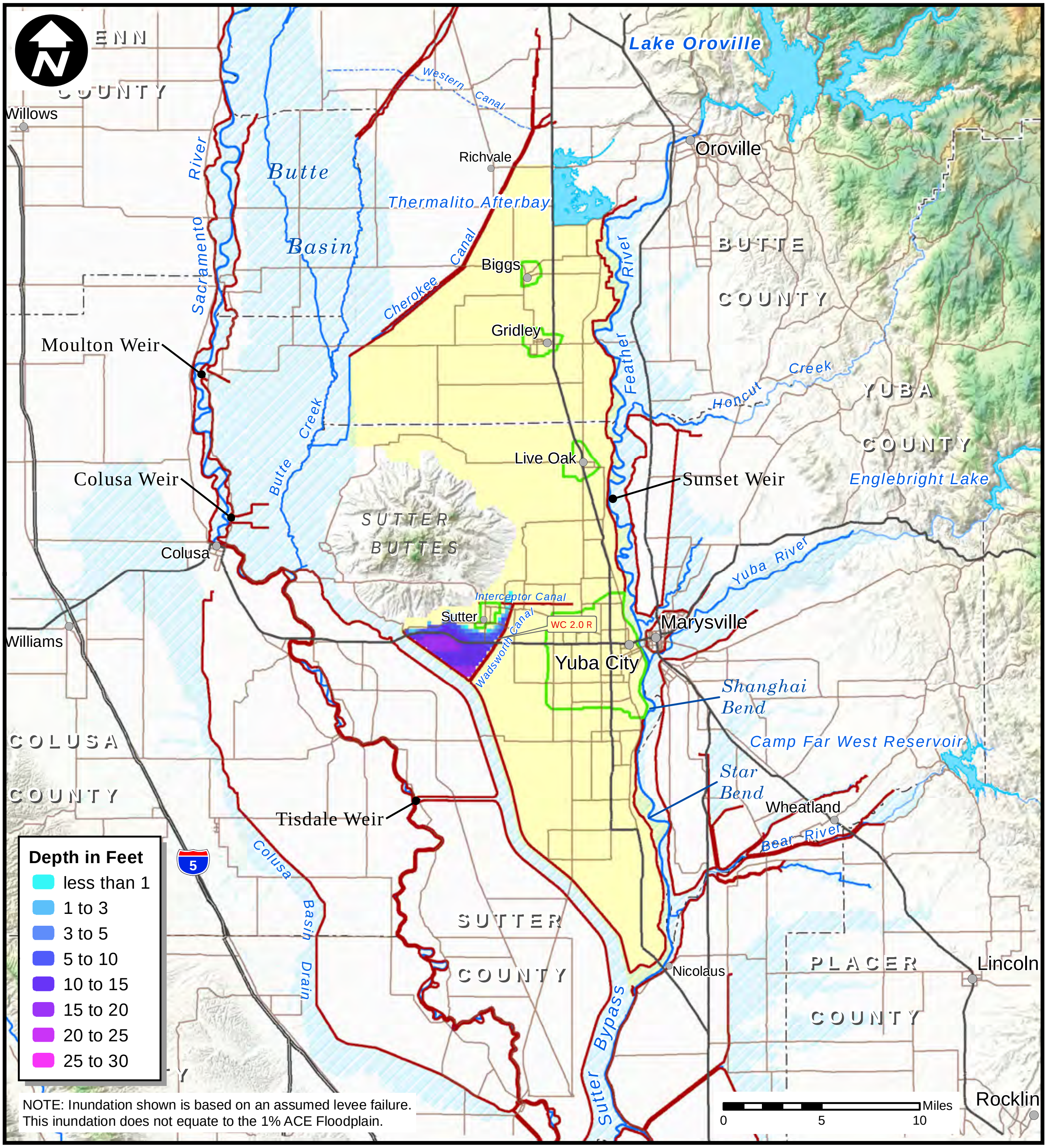
MODELED BREACH INUNDATION
SB 5.0 L INDEX POINT
1% ACE EVENT

U.S. ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT

Prepared by Jim Mars

OCT 2012

PLATE 24



Legend

Breach Index Point	Study Area Extent
Designated Floodways	Federal Levee
Lake or Reservoir	County Boundary
River or Stream	City or Town

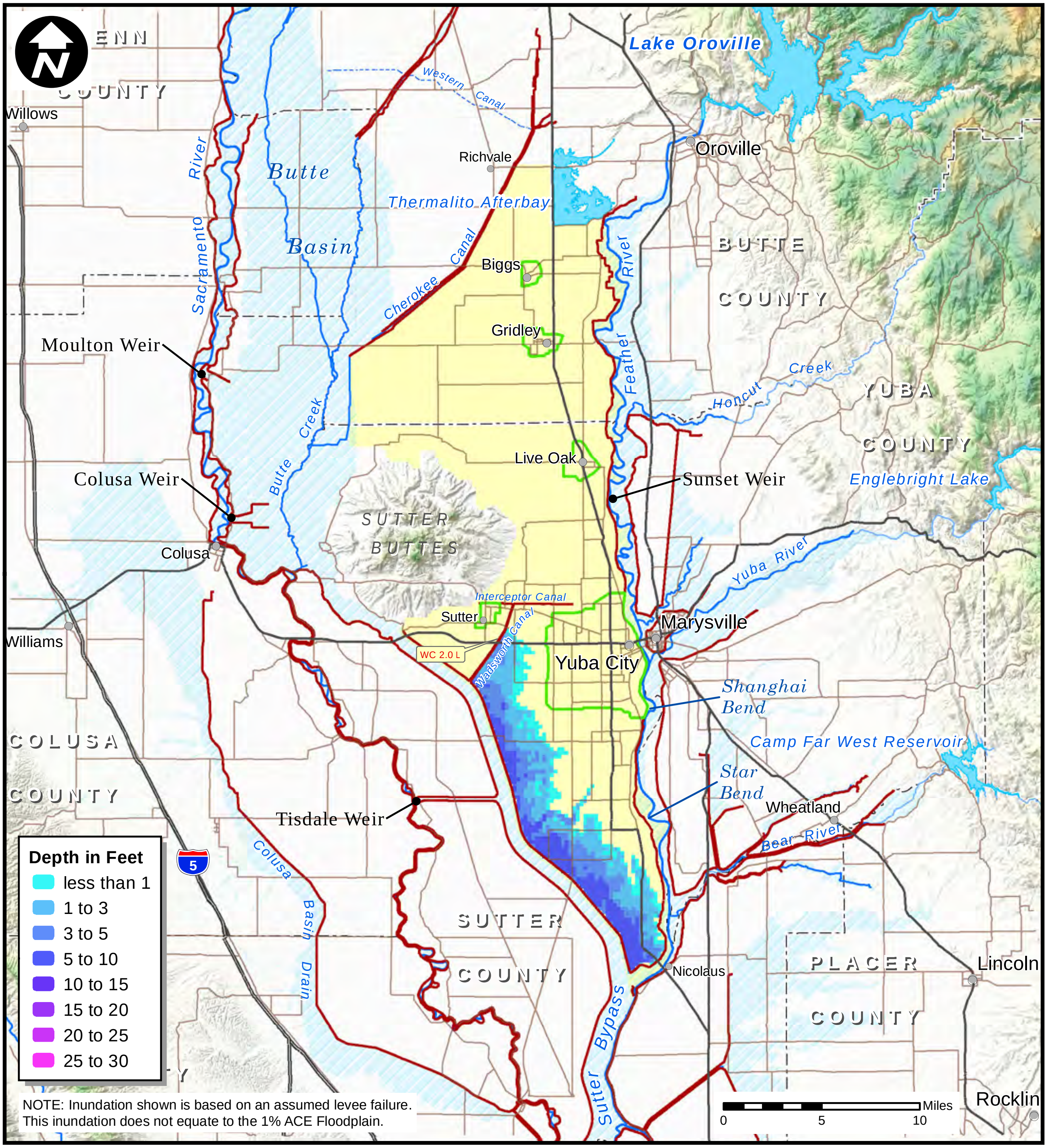
SUTTER BASIN PILOT FEASIBILITY STUDY
SUTTER BASIN, CALIFORNIA

MODELED BREACH INUNDATION WC 2.0 R INDEX POINT 1% ACE EVENT

U.S. ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT

Prepared by Jim Mars

OCT 2012



Legend

Breach Index Point	Study Area Extent
Designated Floodways	Federal Levee
Lake or Reservoir	County Boundary
River or Stream	City or Town

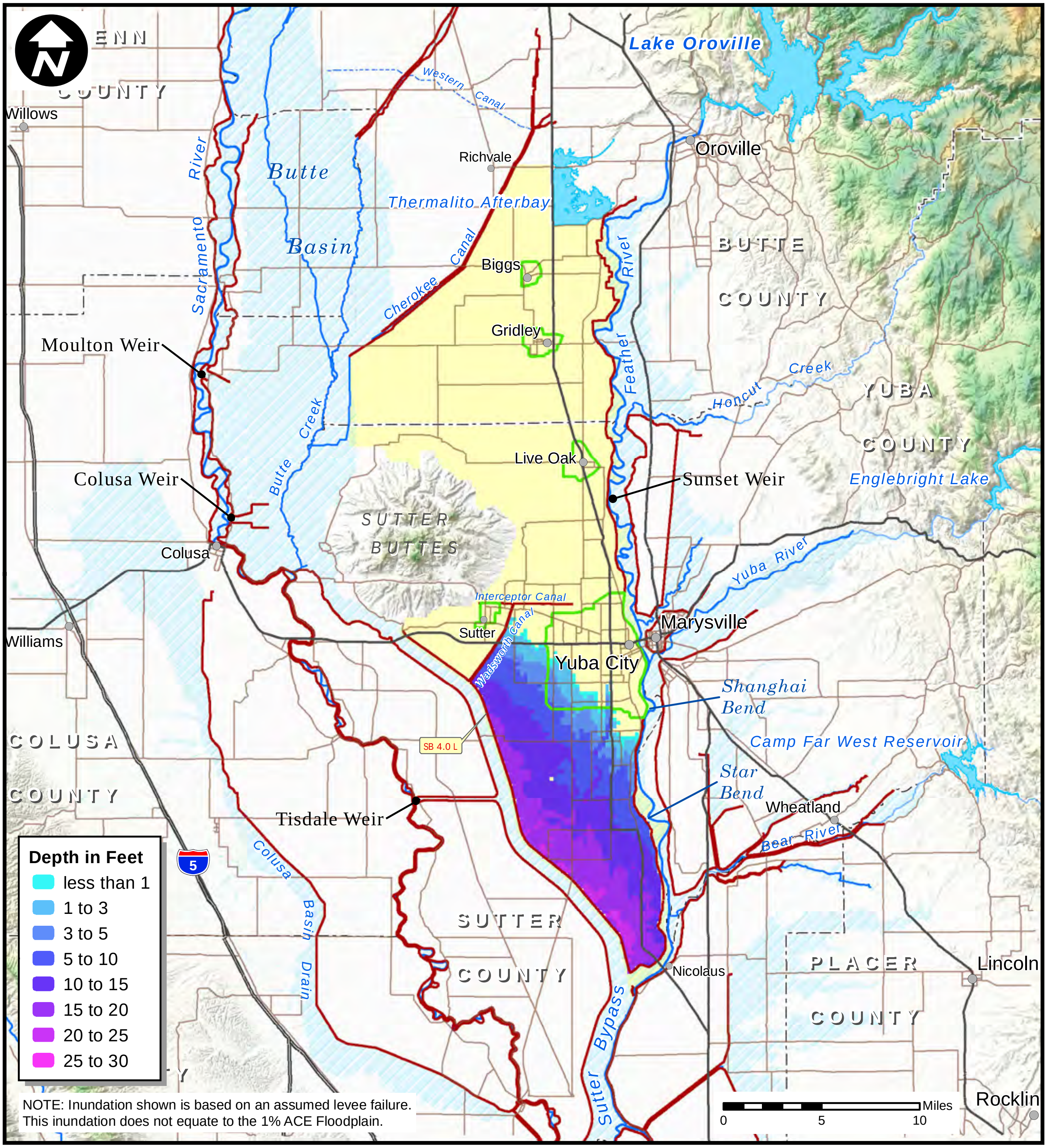
SUTTER BASIN PILOT FEASIBILITY STUDY
SUTTER BASIN, CALIFORNIA

MODELED BREACH INUNDATION
WC 2.0 L INDEX POINT
1% ACE EVENT

U.S. ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT

Prepared by Jim Mars

OCT 2012



Legend

- Breach Index Point
- Designated Floodways
- Lake or Reservoir
- River or Stream
- Study Area Extent
- Federal Levee
- County Boundary
- City or Town

SUTTER BASIN PILOT FEASIBILITY STUDY
SUTTER BASIN, CALIFORNIA

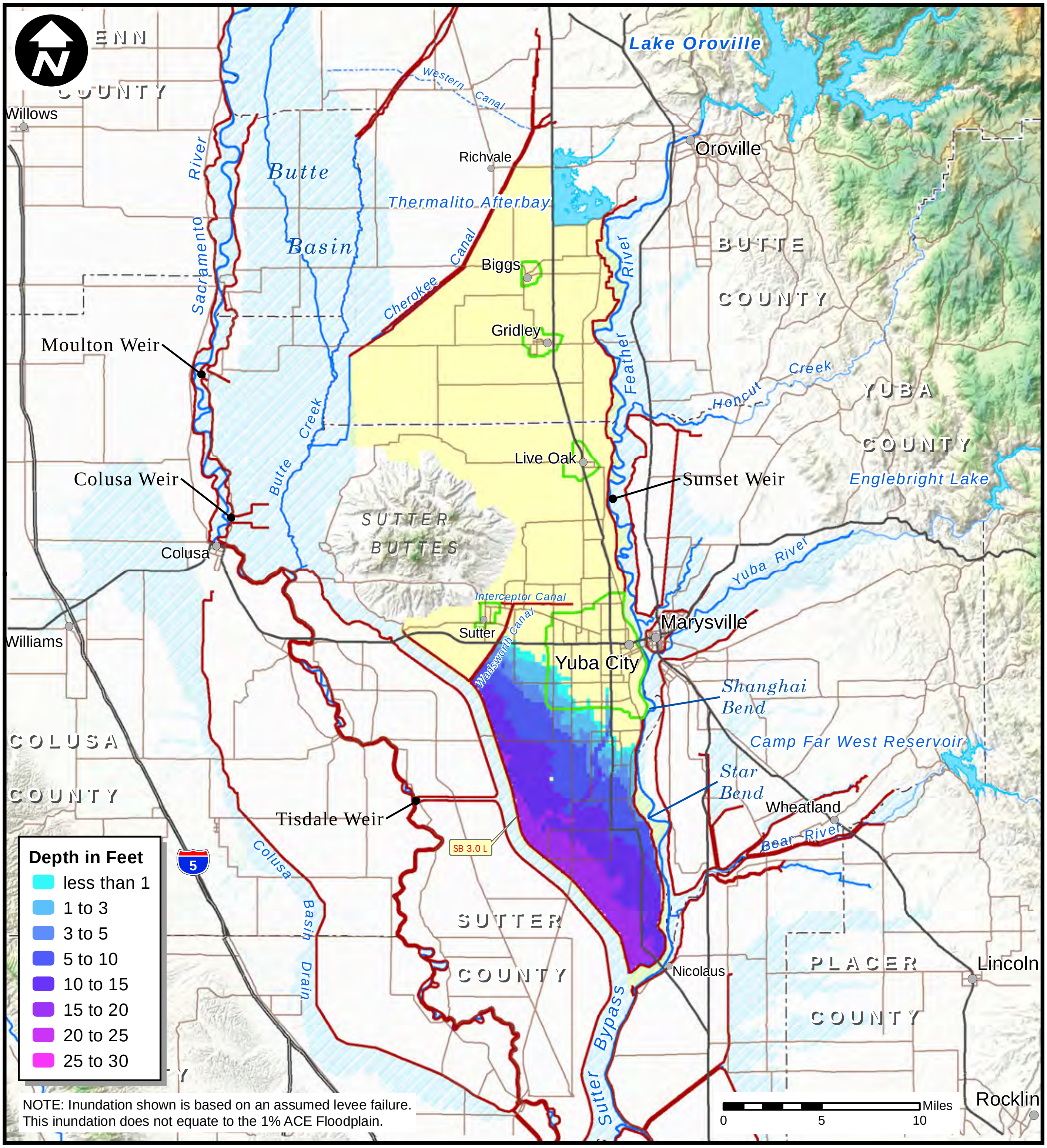
MODELED BREACH INUNDATION
SB 4.0 L INDEX POINT
1% ACE EVENT

U.S. ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT

Prepared by Jim Mars

OCT 2012

PLATE 27



Legend

Breach Index Point	Study Area Extent
Designated Floodways	Federal Levee
Lake or Reservoir	County Boundary
River or Stream	City or Town

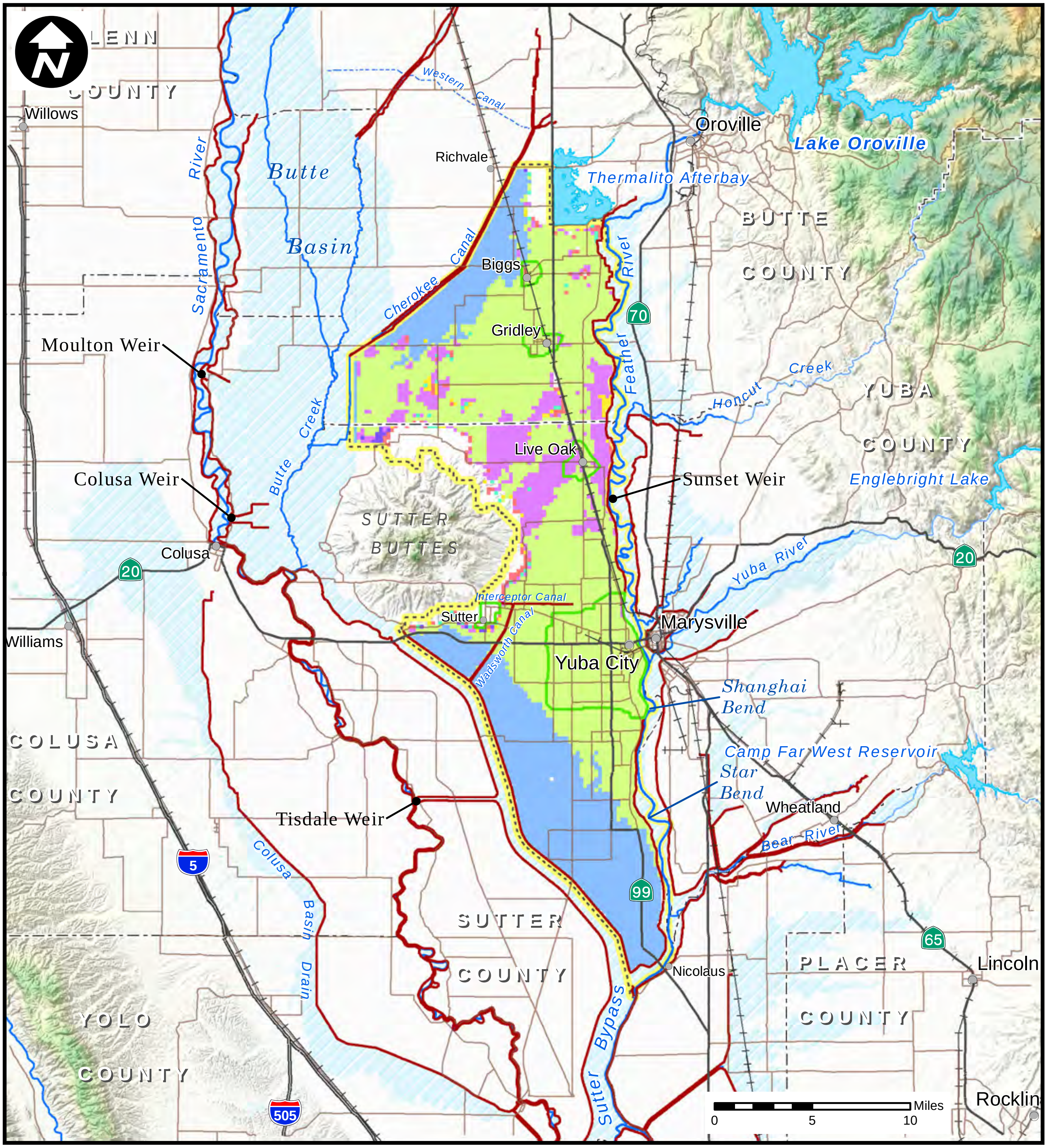
SUTTER BASIN PILOT FEASIBILITY STUDY
SUTTER BASIN, CALIFORNIA

MODELED BREACH INUNDATION SB 3.0 L INDEX POINT 1% ACE EVENT

U.S. ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT

Prepared by Jim Mars

OCT 2012



Legend

- 0.2% (1/500) ACE Floodplain
- 0.5% (1/200) ACE Floodplain
- 1% (1/100) AEP Floodplain
- 2% (1/50) ACE Floodplain
- 4% (1/25) ACE Floodplain
- 10% (1/10) ACE Floodplain
- 50% (1/2) ACE Floodplain
- Federal Levee
- Study Area Extent
- Designated Floodways
- Lake or Reservoir
- River or Stream
- Railroad

Criteria 1 residual floodplain shown if geotechnical probability of failue is greater than 5% at median top of levee or top of levee less than 3 feet above median water surface elevation,

SUTTER BASIN PILOT FEASIBILITY STUDY
SUTTER BASIN, CALIFORNIA

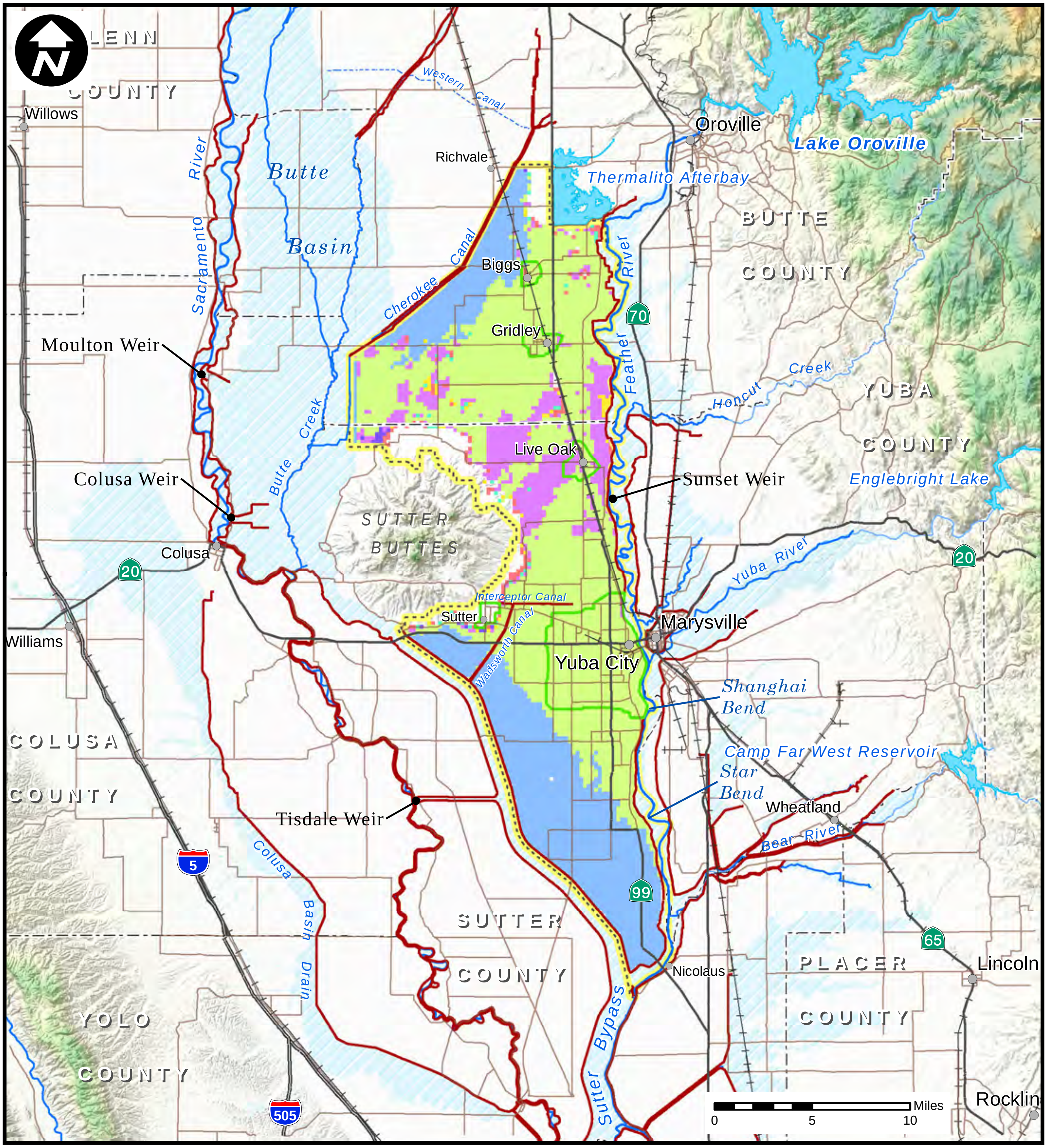
CRITERIA 1 RESIDUAL FLOODPLAIN ALTERNATIVE SB-1 WITHOUT PROJECT

U.S. ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT

Prepared by Jim Mars

OCT 2012

PLATE 29



Legend

- 0.2% (1/500) ACE Floodplain
- 0.5% (1/200) ACE Floodplain
- 1% (1/100) AEP Floodplain
- 2% (1/50) ACE Floodplain
- 4% (1/25) ACE Floodplain
- 10% (1/10) ACE Floodplain
- 50% (1/2) ACE Floodplain
- Federal Levee
- Study Area Extent
- Designated Floodways
- Lake or Reservoir
- River or Stream
- Railroad

Criteria 2 Residual flooplain shown if levee does not pass criteria.
1) Assurance less than 90% the levee does not pass criteria
2) For assurance between 90 and 95% levee must have minimum of 3 feet of freeboard to pass criteria. 3) For assurance greater than 95% levee must have minimum of 2 feet of freeboard to pass criteria

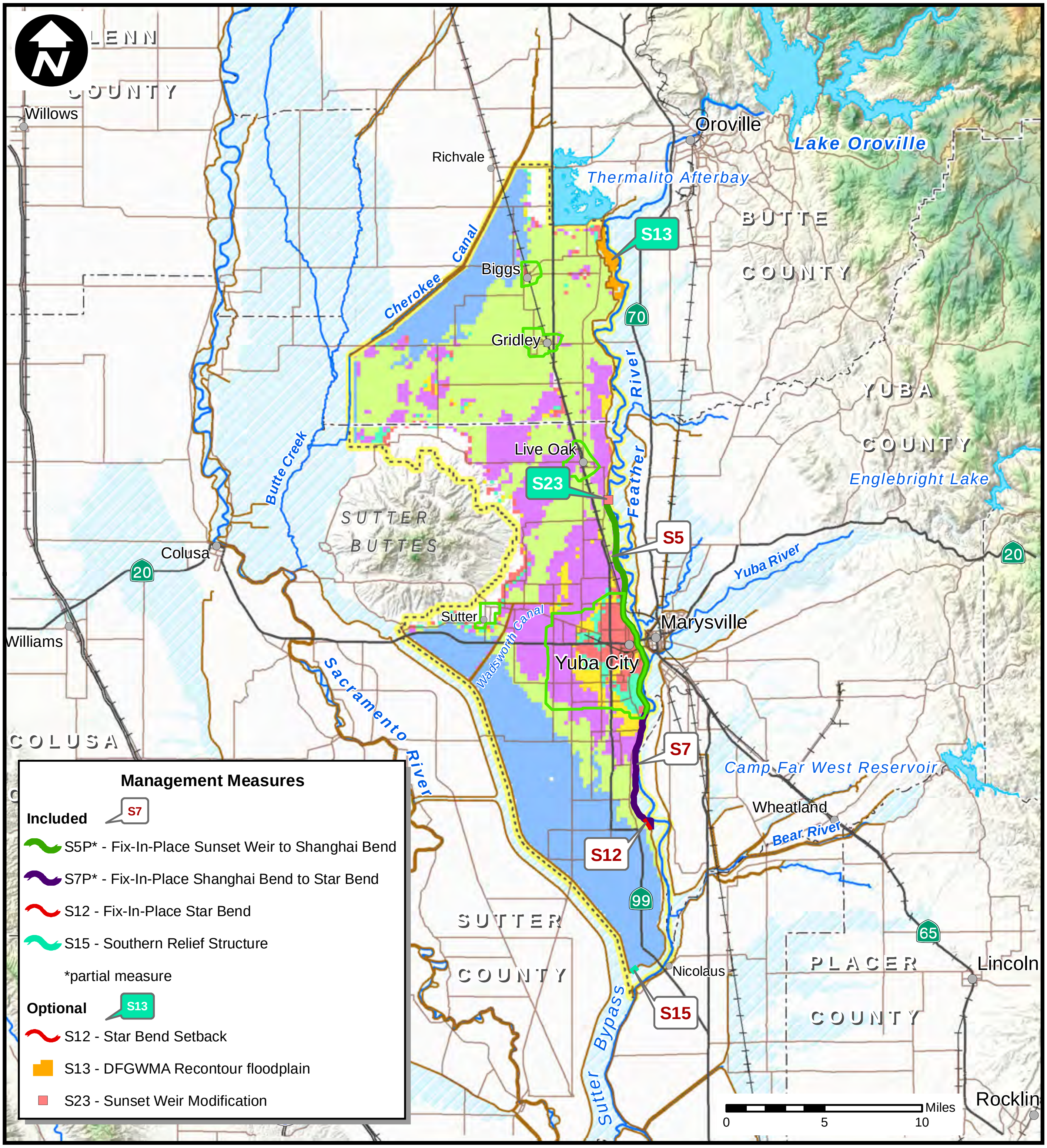
SUTTER BASIN PILOT FEASIBILITY STUDY
SUTTER BASIN, CALIFORNIA

CRITERIA 2 RESIDUAL FLOODPLAIN ALTERNATIVE SB-1 WITHOUT PROJECT

U.S. ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT

Prepared by Jim Mars

OCT 2012



Legend

- 0.2% (1/500) ACE Floodplain
- 0.5% (1/200) ACE Floodplain
- 1% (1/100) AEP Floodplain
- 2% (1/50) ACE Floodplain
- 4% (1/25) ACE Floodplain
- 10% (1/10) ACE Floodplain
- 50% (1/2) ACE Floodplain
- Federal Levee
- Study Area Extent
- Designated Floodways
- Lake or Reservoir
- River or Stream
- Railroad

Criteria 1 residual floodplain shown if geotechnical probability of failue is greater than 5% at median top of levee or top of levee less than 3 feet above median water surface elevation,

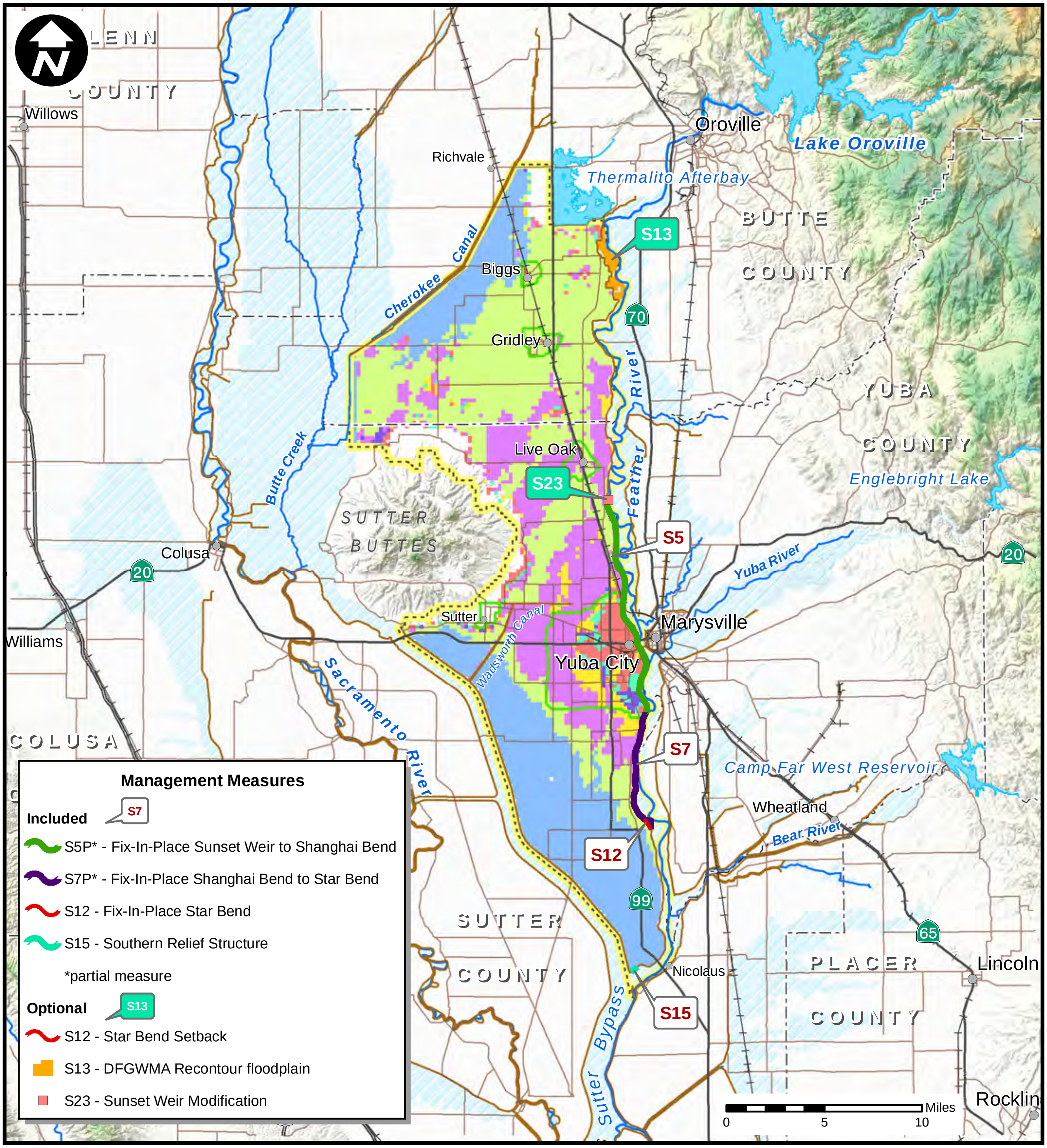
SUTTER BASIN PILOT FEASIBILITY STUDY
SUTTER BASIN, CALIFORNIA

CRITERIA 1 RESIDUAL FLOODPLAIN ALTERNATIVE SB-2 MINIMAL FIX-IN-PLACE PLUS NONSTRUCTURAL

U.S. ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT

Prepared by Jim Mars

OCT 2012



Legend

- 0.2% (1/500) ACE Floodplain
- 0.5% (1/200) ACE Floodplain
- 1% (1/100) AEP Floodplain
- 2% (1/50) ACE Floodplain
- 4% (1/25) ACE Floodplain
- 10% (1/10) ACE Floodplain
- 50% (1/2) ACE Floodplain
- Federal Levee
- Study Area Extent
- Designated Floodways
- Lake or Reservoir
- River or Stream
- Railroad

Criteria 2 Residual flooplain shown if levee does not pass criteria.
1) Assurance less than 90% the levee does not pass criteria
2) For assurance between 90 and 95% levee must have minimum of 3 feet of freeboard to pass criteria. 3) For assurance greater than 95% levee must have minimum of 2 feet of freeboard to pass criteria

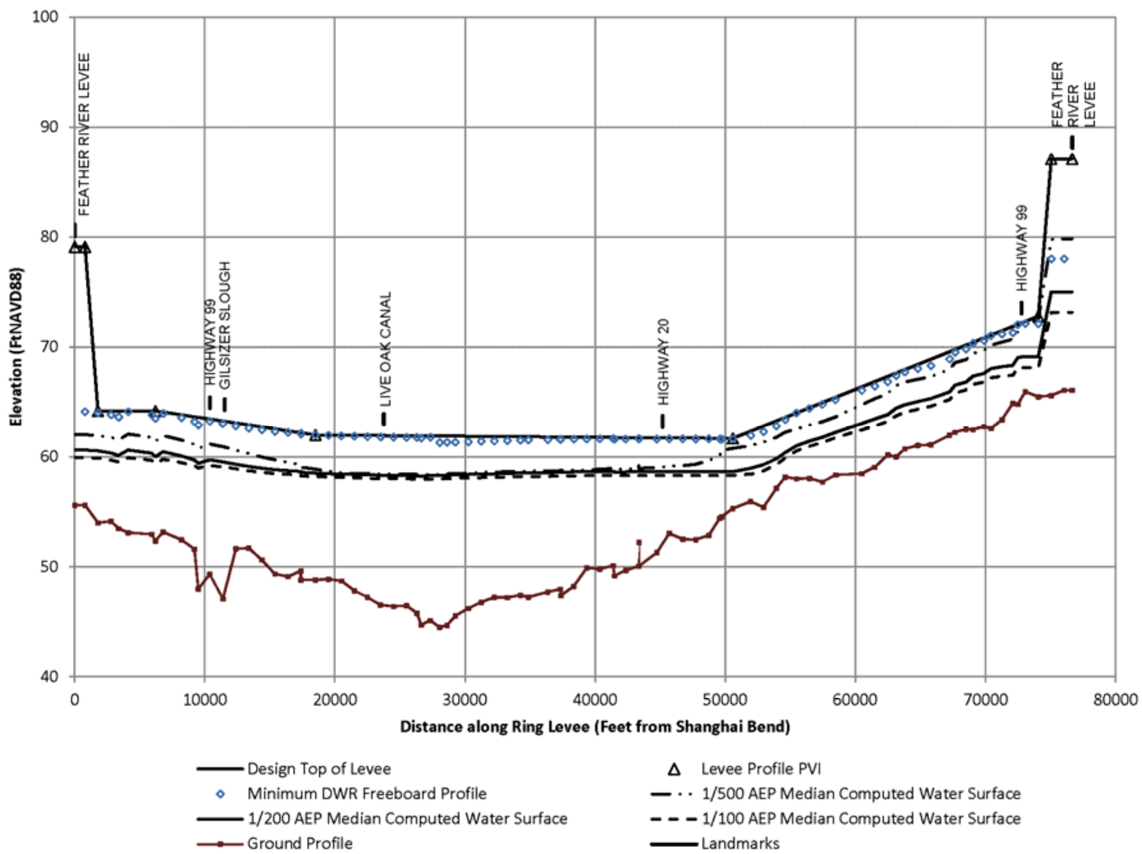
SUTTER BASIN PILOT FEASIBILITY STUDY
SUTTER BASIN, CALIFORNIA

CRITERIA 2 RESIDUAL FLOODPLAIN ALTERNATIVE SB-2 MINIMAL FIX-IN-PLACE PLUS NONSTRUCTURAL

U.S. ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT

Prepared by Jim Mars

OCT 2012



Notes:

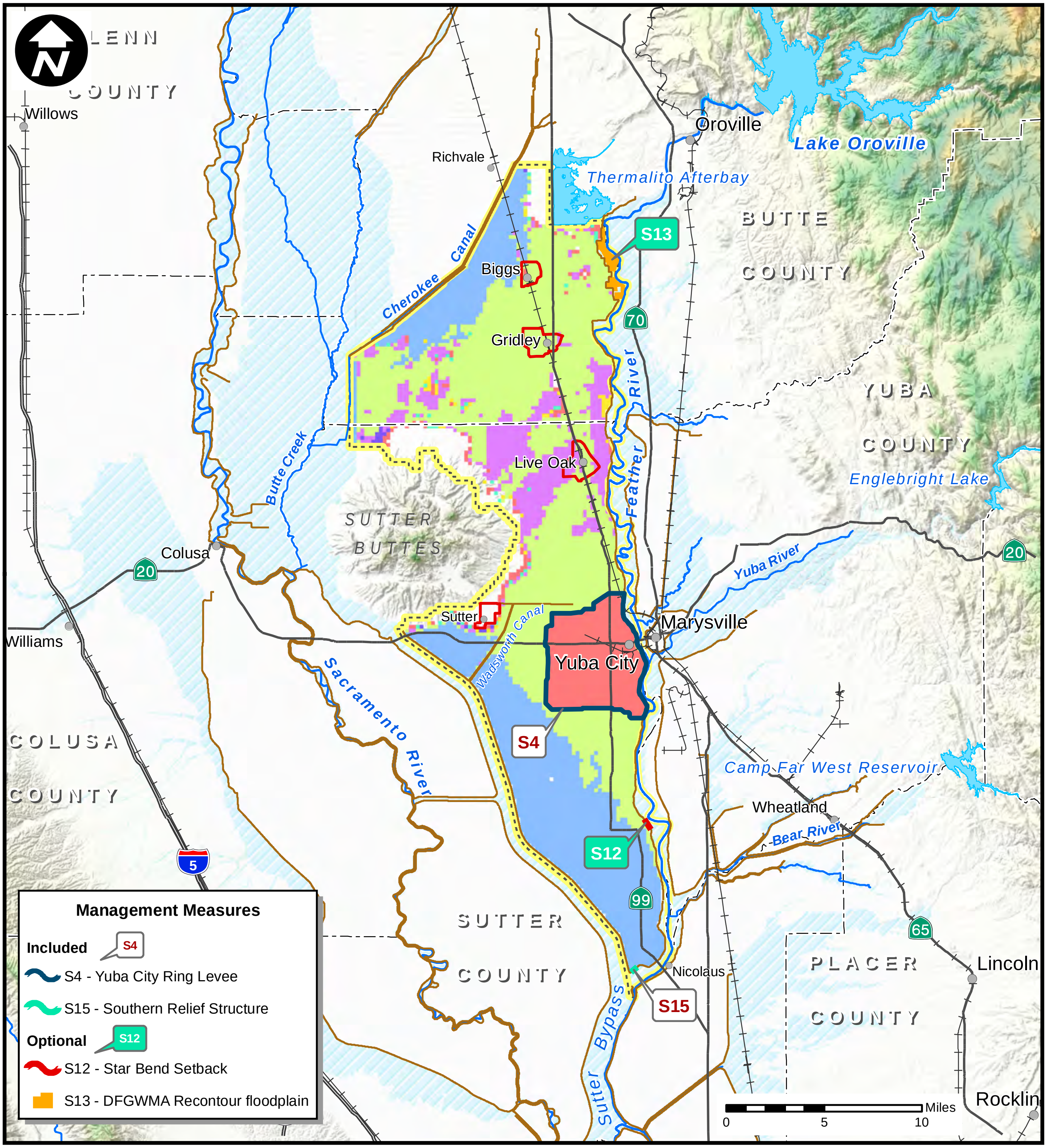
1) WSEL = Water Surface Elevation

2) Water surface elevations based on maximum water surface from assumed levee breaches outside the ring levee.

SUTTER BASIN FEASBILITY STUDY
SUTTER BASIN, CALIFORNIA

LEVEE DESIGN PROFILE
ALTERNATIVE SB-3
YUBA CITY RING LEVEE

U.S ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT



Legend

- 0.2% (1/500) ACE Floodplain
- 0.5% (1/200) ACE Floodplain
- 1% (1/100) AEP Floodplain
- 2% (1/50) ACE Floodplain
- 4% (1/25) ACE Floodplain
- 10% (1/10) ACE Floodplain
- 50% (1/2) ACE Floodplain
- Federal Levee
- Study Area Extent
- Designated Floodways
- Lake or Reservoir
- River or Stream
- Railroad

Criteria 1 residual floodplain shown if geotechnical probability of failue is greater than 5% at median top of levee or top of levee less than 3 feet above median water surface elevation,

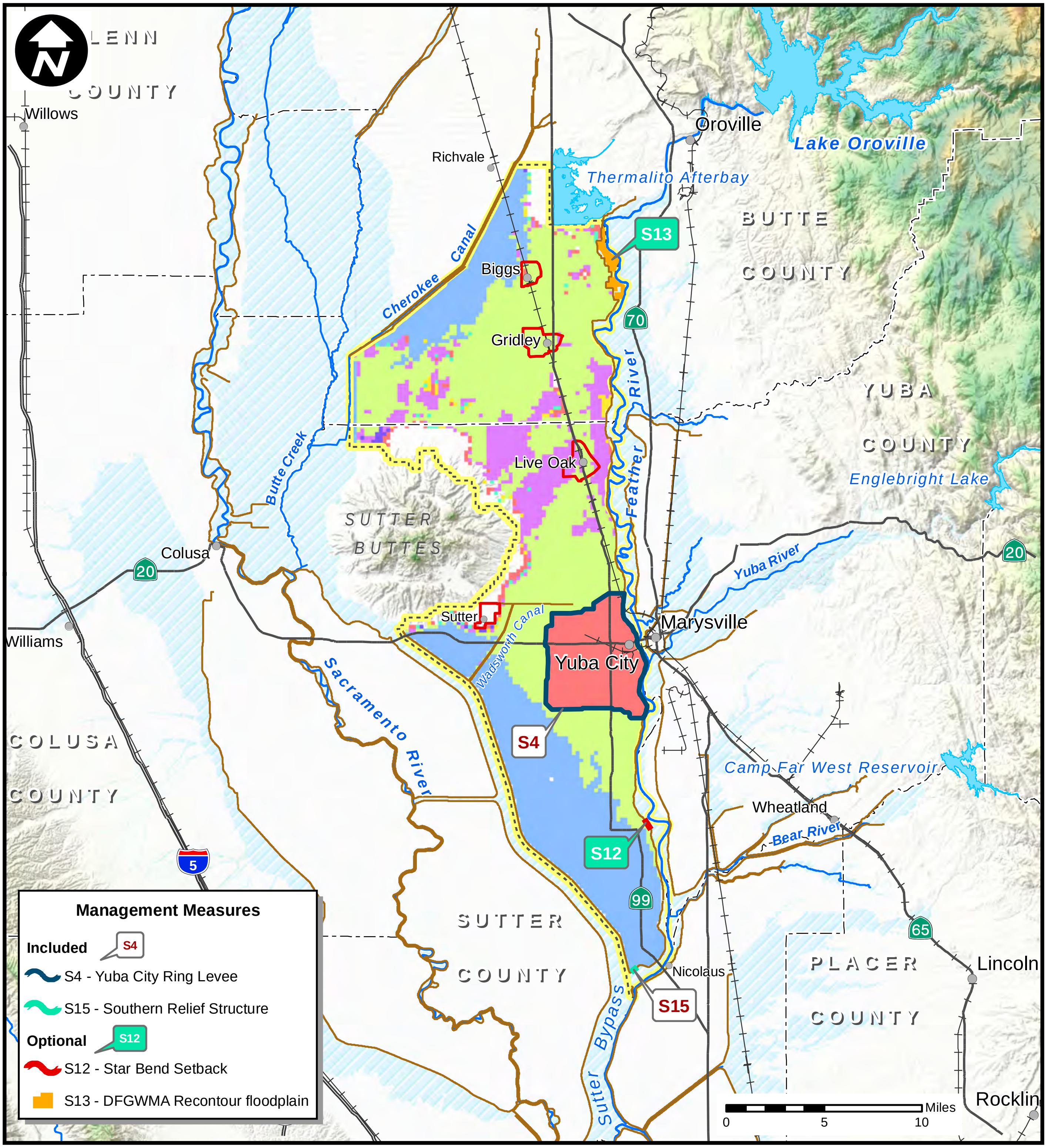
SUTTER BASIN PILOT FEASIBILITY STUDY
SUTTER BASIN, CALIFORNIA

CRITERIA 1 RESIDUAL FLOODPLAIN ALTERNATIVE SB-3 YUBA CITY RING LEVEE

U.S. ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT

Prepared by Jim Mars

OCT 2012



Legend

- 0.2% (1/500) ACE Floodplain
- 0.5% (1/200) ACE Floodplain
- 1% (1/100) AEP Floodplain
- 2% (1/50) ACE Floodplain
- 4% (1/25) ACE Floodplain
- 10% (1/10) ACE Floodplain
- 50% (1/2) ACE Floodplain
- Federal Levee
- Study Area Extent
- Designated Floodways
- Lake or Reservoir
- River or Stream
- Railroad

Criteria 2 Residual flooplain shown if levee does not pass criteria.
1) Assurance less than 90% the levee does not pass criteria
2) For assurance between 90 and 95% levee must have minimum of 3 feet of freeboard to pass criteria. 3) For assurance greater than 95% levee must have minimum of 2 feet of freeboard to pass criteria

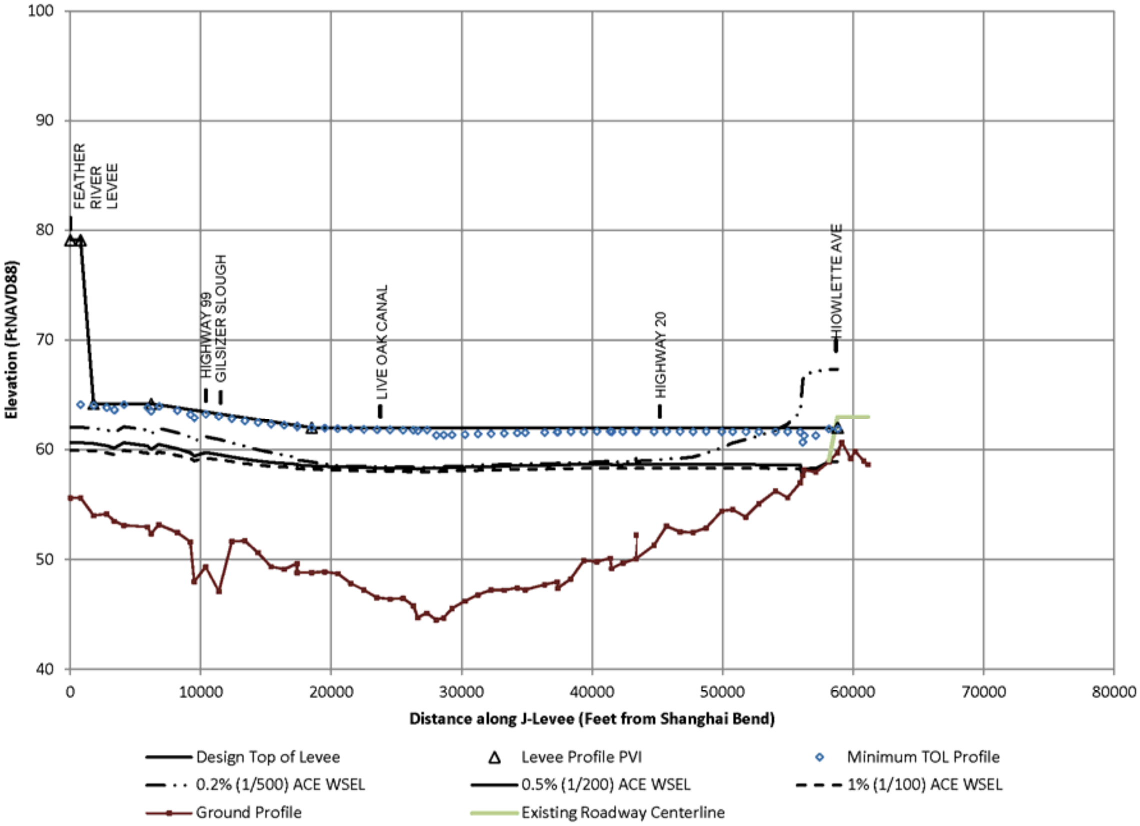
SUTTER BASIN PILOT FEASIBILITY STUDY
SUTTER BASIN, CALIFORNIA

CRITERIA 2 RESIDUAL FLOODPLAIN ALTERNATIVE SB-3 YUBA CITY RING LEVEE

U.S. ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT

Prepared by Jim Mars

OCT 2012



Notes:

1) WSEL = Water Surface Elevation

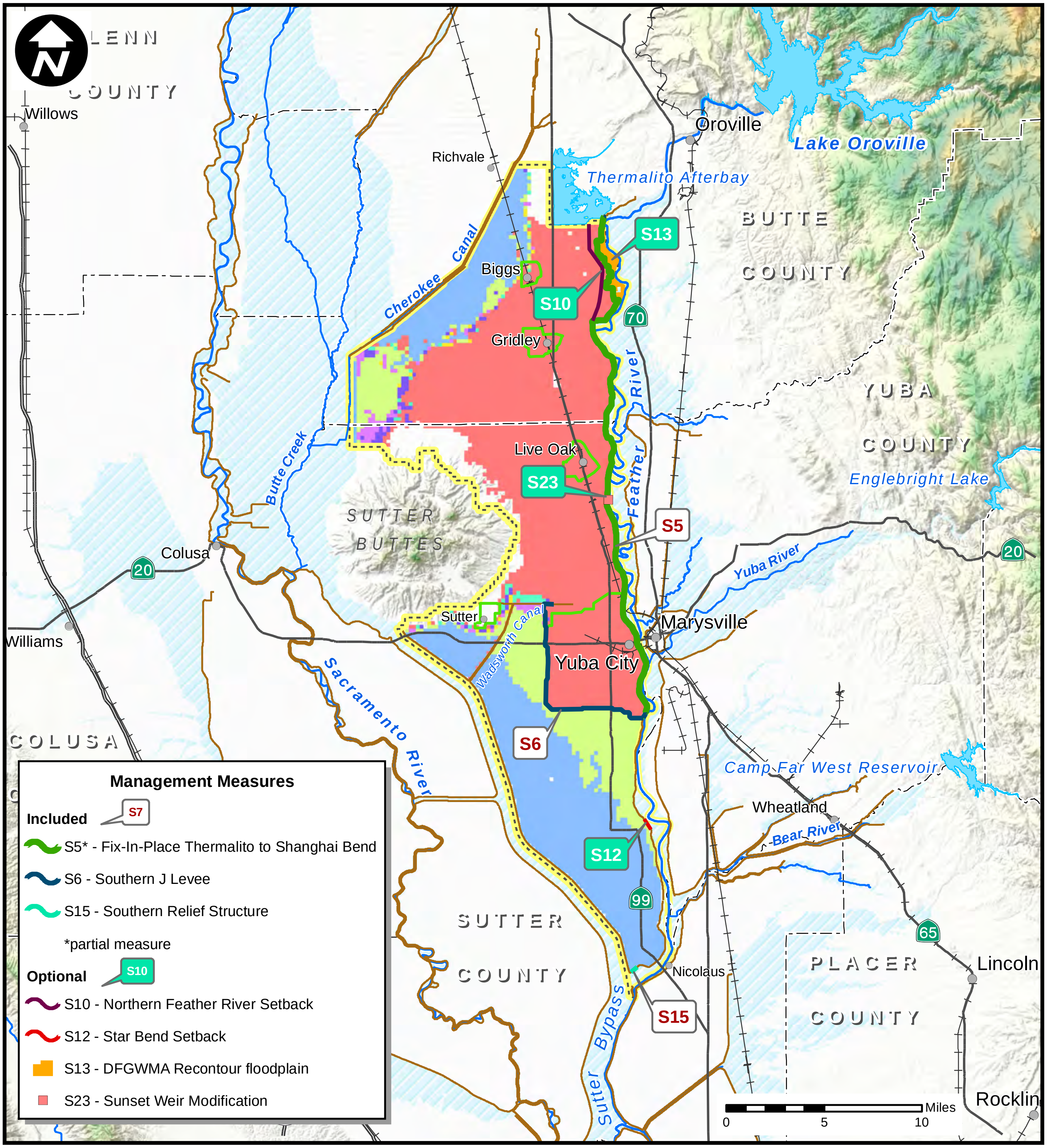
2) Water surface elevations based on maximum water surface from assumed levee breaches outside the ring levee.

SUTTER BASIN FEASBILITY STUDY
SUTTER BASIN, CALIFORNIA

LEVEE DESIGN PROFILE
ALTERNATIVE SB-4
LITTLE “J” LEVEE

U.S ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT

OCT 2012



Legend

- 0.2% (1/500) ACE Floodplain
- 0.5% (1/200) ACE Floodplain
- 1% (1/100) AEP Floodplain
- 2% (1/50) ACE Floodplain
- 4% (1/25) ACE Floodplain
- 10% (1/10) ACE Floodplain
- 50% (1/2) ACE Floodplain
- Federal Levee
- Study Area Extent
- Designated Floodways
- Lake or Reservoir
- River or Stream
- Railroad

Criteria 1 residual floodplain shown if geotechnical probability of failue is greater than 5% at median top of levee or top of levee less than 3 feet above median water surface elevation,

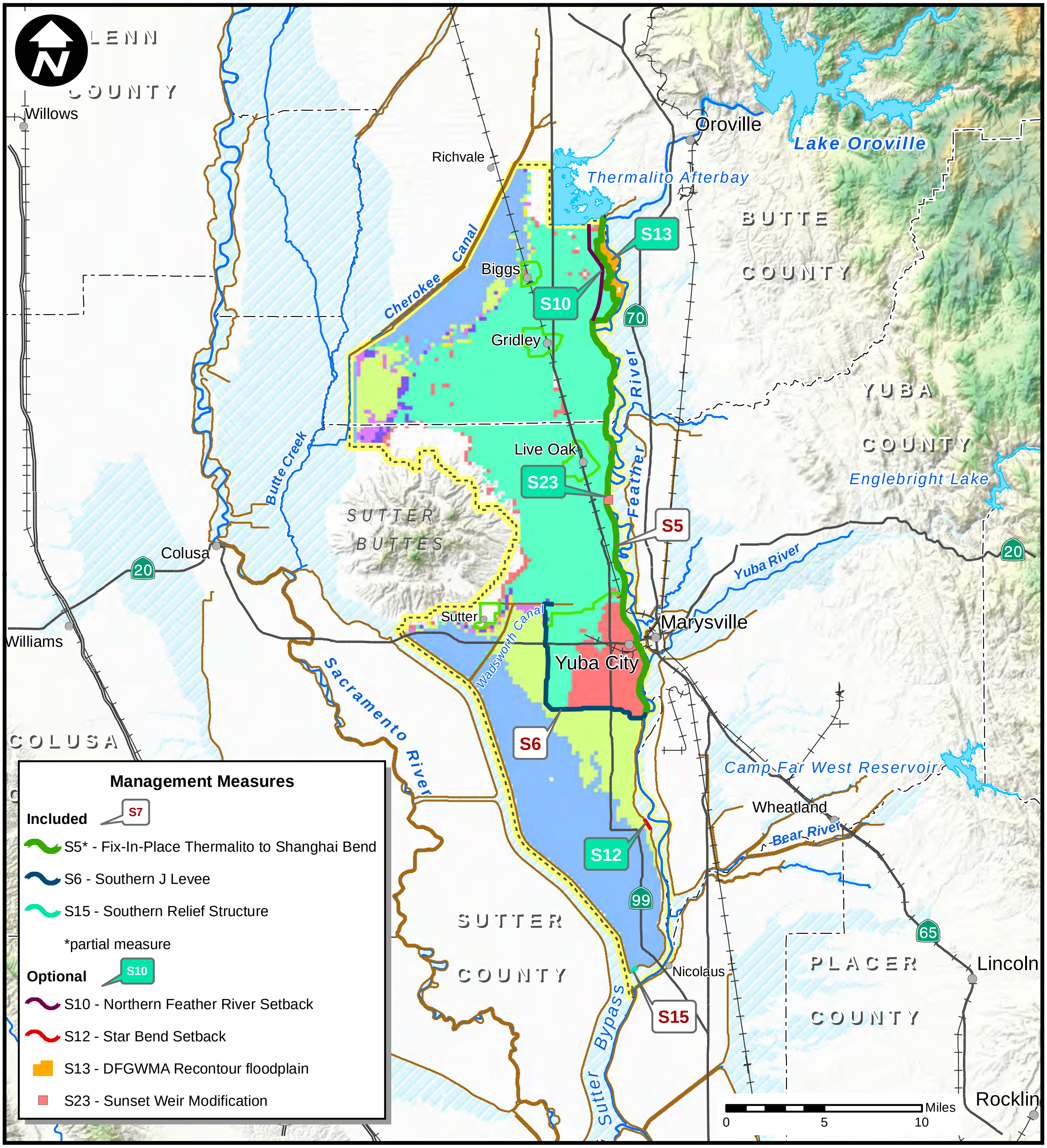
SUTTER BASIN PILOT FEASIBILITY STUDY
SUTTER BASIN, CALIFORNIA

CRITERIA 1 RESIDUAL FLOODPLAIN ALTERNATIVE SB-4 LITTLE "J" LEVEE

U.S. ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT

Prepared by Jim Mars

OCT 2012



Legend

- 0.2% (1/500) ACE Floodplain
- 0.5% (1/200) ACE Floodplain
- 1% (1/100) AEP Floodplain
- 2% (1/50) ACE Floodplain
- 4% (1/25) ACE Floodplain
- 10% (1/10) ACE Floodplain
- 50% (1/2) ACE Floodplain
- Federal Levee
- Study Area Extent
- Designated Floodways
- Lake or Reservoir
- River or Stream
- Railroad

Criteria 2 Residual flooplain shown if levee does not pass criteria.
1) Assurance less than 90% the levee does not pass criteria
2) For assurance between 90 and 95% levee must have minimum of 3 feet of freeboard to pass criteria. 3) For assurance greater than 95% levee must have minimum of 2 feet of freeboard to pass criteria

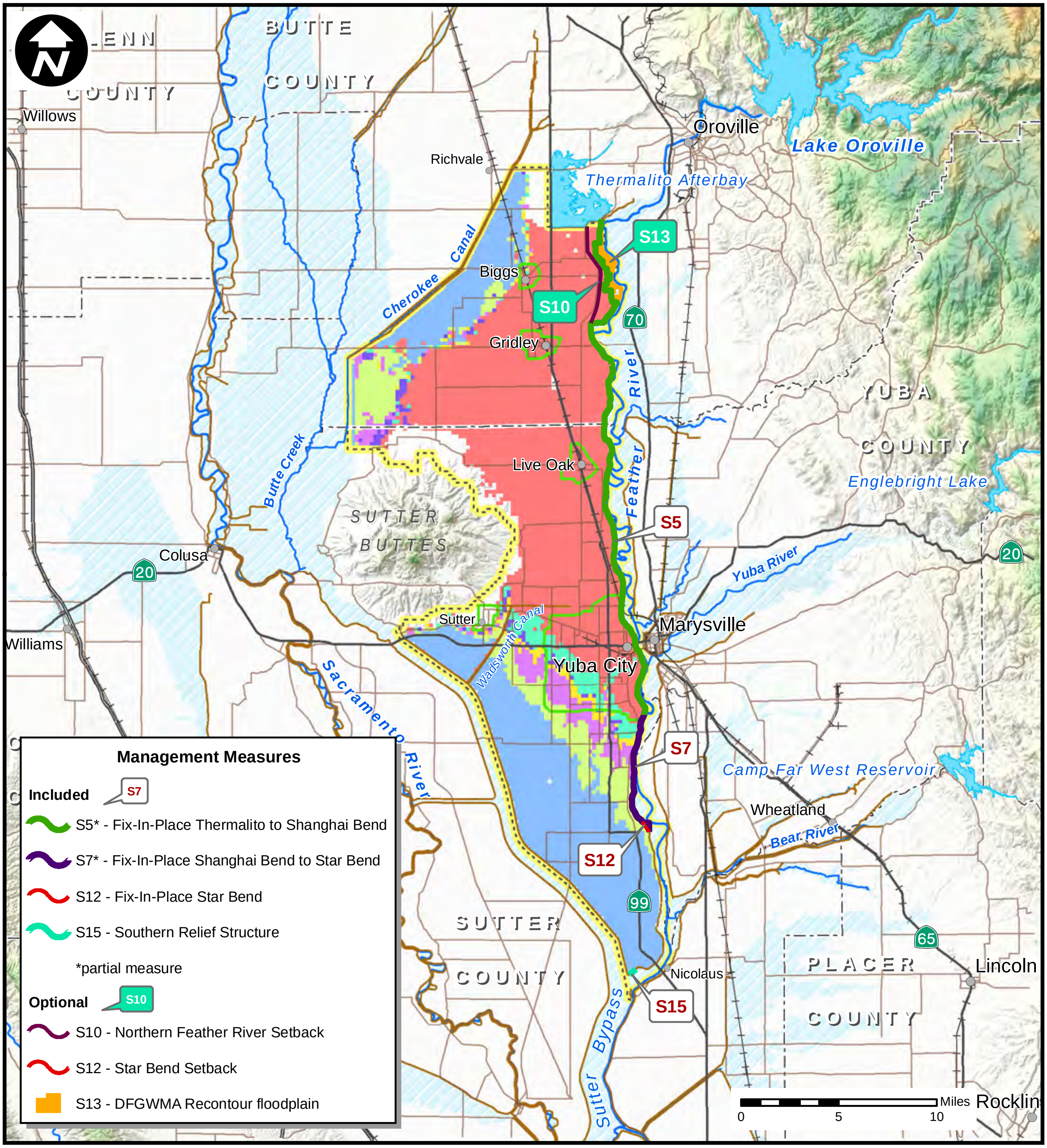
SUTTER BASIN PILOT FEASIBILITY STUDY
SUTTER BASIN, CALIFORNIA

CRITERIA 2 RESIDUAL FLOODPLAIN ALTERNATIVE SB-4 LITTLE "J" LEVEE

U.S. ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT

Prepared by Jim Mars

OCT 2012



Legend

- 0.2% (1/500) ACE Floodplain
- 0.5% (1/200) ACE Floodplain
- 1% (1/100) AEP Floodplain
- 2% (1/50) ACE Floodplain
- 4% (1/25) ACE Floodplain
- 10% (1/10) ACE Floodplain
- 50% (1/2) ACE Floodplain
- Federal Levee
- Study Area Extent
- Designated Floodways
- Lake or Reservoir
- River or Stream
- Railroad

Criteria 1 residual floodplain shown if geotechnical probability of failue is greater than 5% at median top of levee or top of levee less than 3 feet above median water surface elevation,

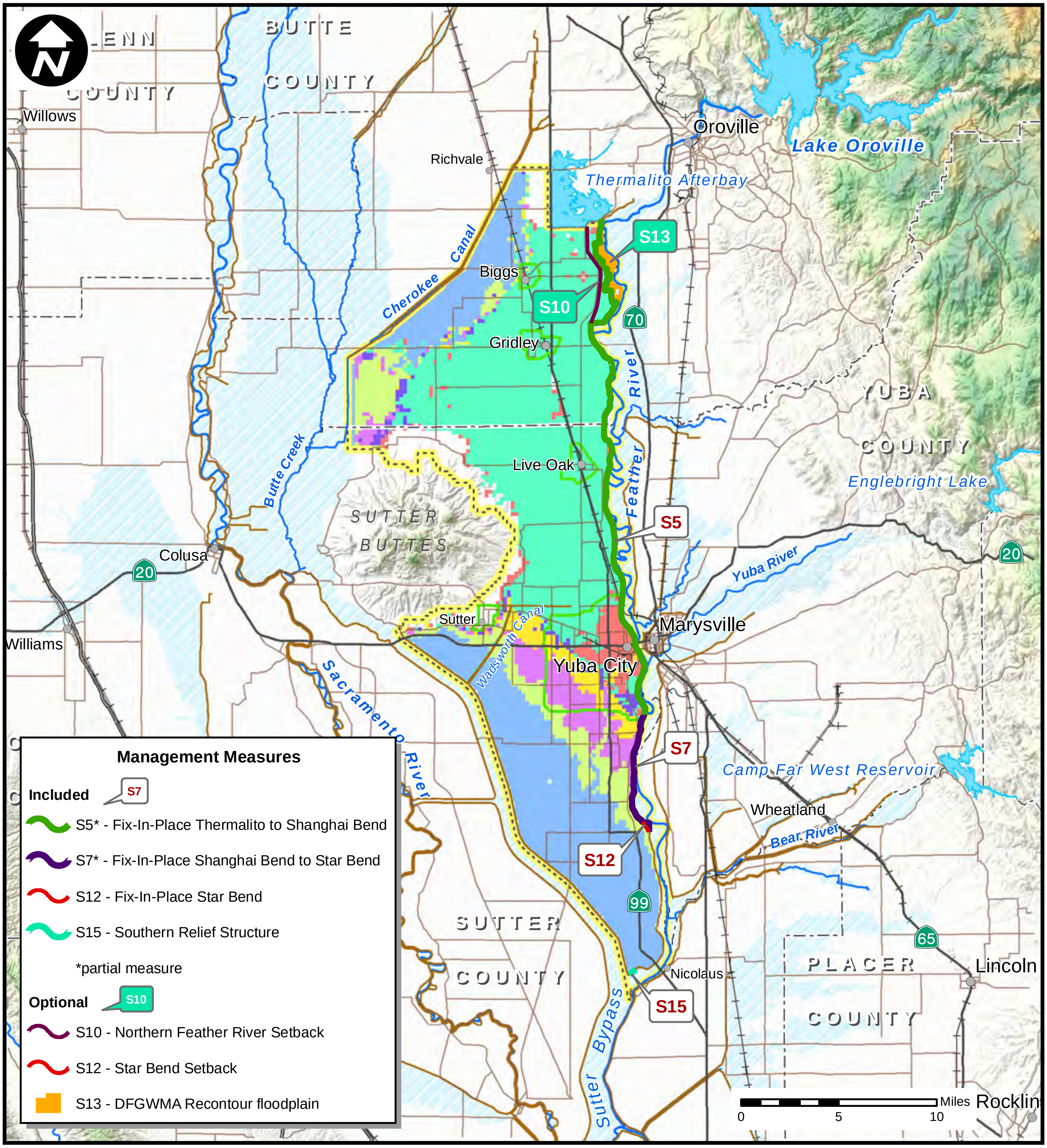
SUTTER BASIN PILOT FEASIBILITY STUDY
SUTTER BASIN, CALIFORNIA

CRITERIA 1 RESIDUAL FLOODPLAIN ALTERNATIVE SB-5 FIX IN PLACE FEATHER RIVER, THERMALITO TO STAR BEND

U.S. ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT

Prepared by Jim Mars

OCT 2012



Legend

- 0.2% (1/500) ACE Floodplain
- 0.5% (1/200) ACE Floodplain
- 1% (1/100) AEP Floodplain
- 2% (1/50) ACE Floodplain
- 4% (1/25) ACE Floodplain
- 10% (1/10) ACE Floodplain
- 50% (1/2) ACE Floodplain
- Federal Levee
- Study Area Extent
- Designated Floodways
- Lake or Reservoir
- River or Stream
- Railroad

Criteria 2 Residual flooplain shown if levee does not pass criteria.
1) Assurance less than 90% the levee does not pass criteria
2) For assurance between 90 and 95% levee must have minimum of 3 feet of freeboard to pass criteria. 3) For assurance greater than 95% levee must have minimum of 2 feet of freeboard to pass criteria

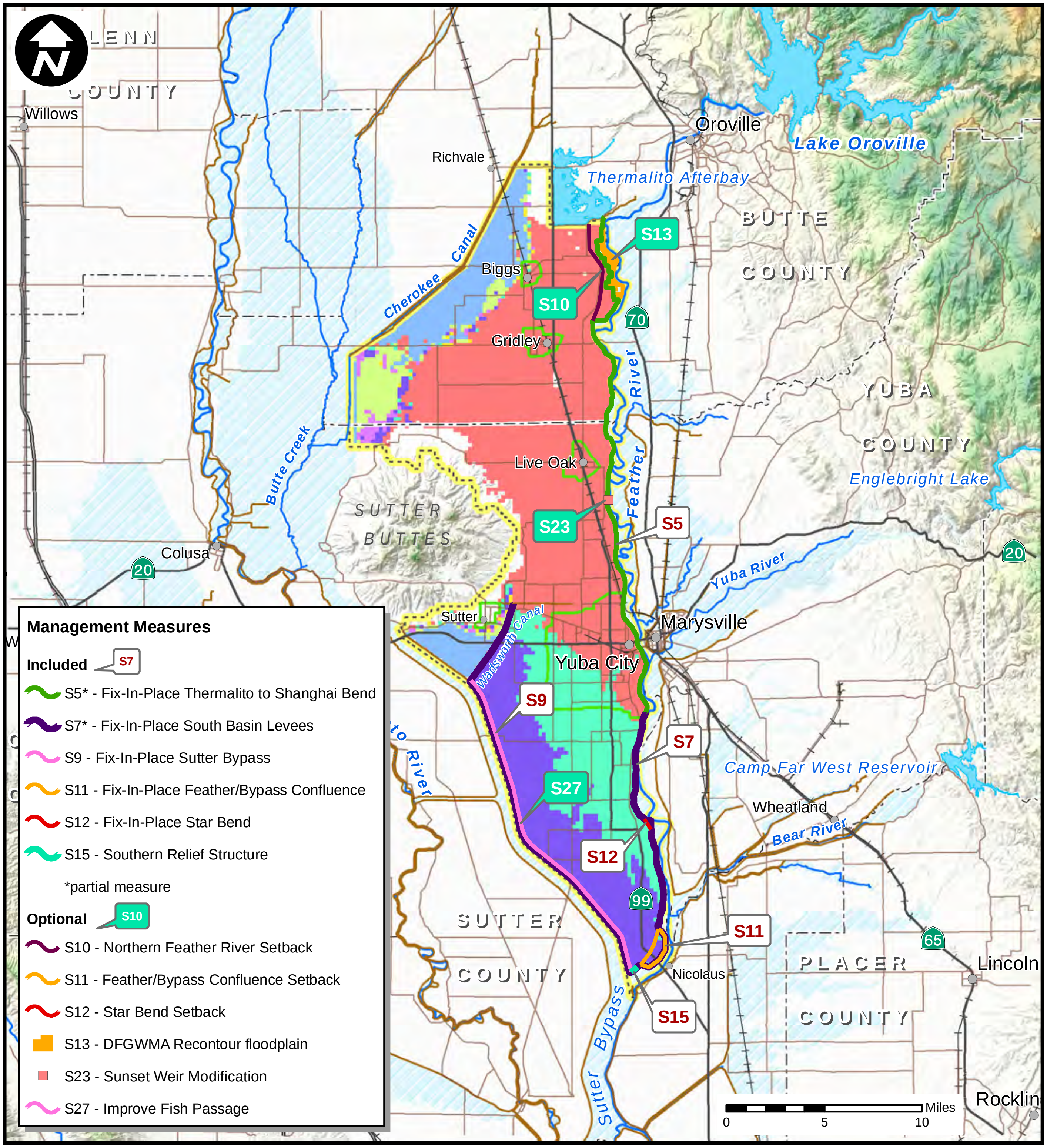
SUTTER BASIN PILOT FEASIBILITY STUDY
SUTTER BASIN, CALIFORNIA

CRITERIA 2 RESIDUAL FLOODPLAIN ALTERNATIVE SB-5 FIX IN PLACE FEATHER RIVER, THERMALITO TO STAR BEND

U.S. ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT

Prepared by Jim Mars

OCT 2012



Legend

- 0.2% (1/500) ACE Floodplain
- 0.5% (1/200) ACE Floodplain
- 1% (1/100) AEP Floodplain
- 2% (1/50) ACE Floodplain
- 4% (1/25) ACE Floodplain
- 10% (1/10) ACE Floodplain
- 50% (1/2) ACE Floodplain
- Federal Levee
- Study Area Extent
- Designated Floodways
- Lake or Reservoir
- River or Stream
- Railroad

Criteria 1 residual floodplain shown if geotechnical probability of failue is greater than 5% at median top of levee or top of levee less than 3 feet above median water surface elevation,

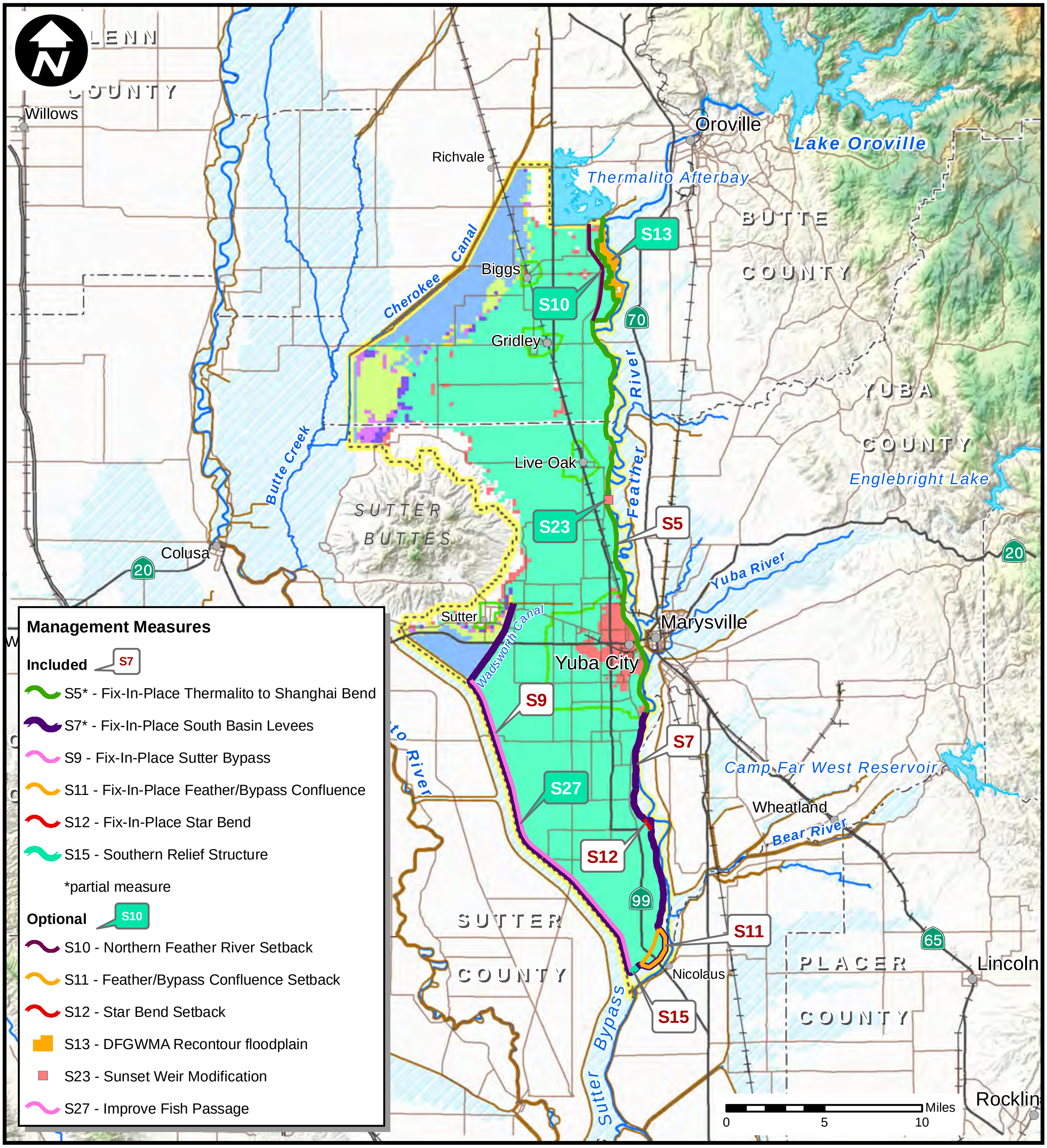
SUTTER BASIN PILOT FEASIBILITY STUDY
SUTTER BASIN, CALIFORNIA

CRITERIA 1 RESIDUAL FLOODPLAIN ALTERNATIVE SB-6 FIX IN PLACE FEATHER RIVER, SUTTER BYPASS, AND WADSWORTH

U.S. ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT

Prepared by Jim Mars

OCT 2012



Legend

- 0.2% (1/500) ACE Floodplain
- 0.5% (1/200) ACE Floodplain
- 1% (1/100) AEP Floodplain
- 2% (1/50) ACE Floodplain
- 4% (1/25) ACE Floodplain
- 10% (1/10) ACE Floodplain
- 50% (1/2) ACE Floodplain
- Federal Levee
- Study Area Extent
- Designated Floodways
- Lake or Reservoir
- River or Stream
- Railroad

Criteria 2 Residual flooplain shown if levee does not pass criteria.
1) Assurance less than 90% the levee does not pass criteria
2) For assurance between 90 and 95% levee must have minimum of 3 feet of freeboard to pass criteria. 3) For assurance greater than 95% levee must have minimum of 2 feet of freeboard to pass criteria

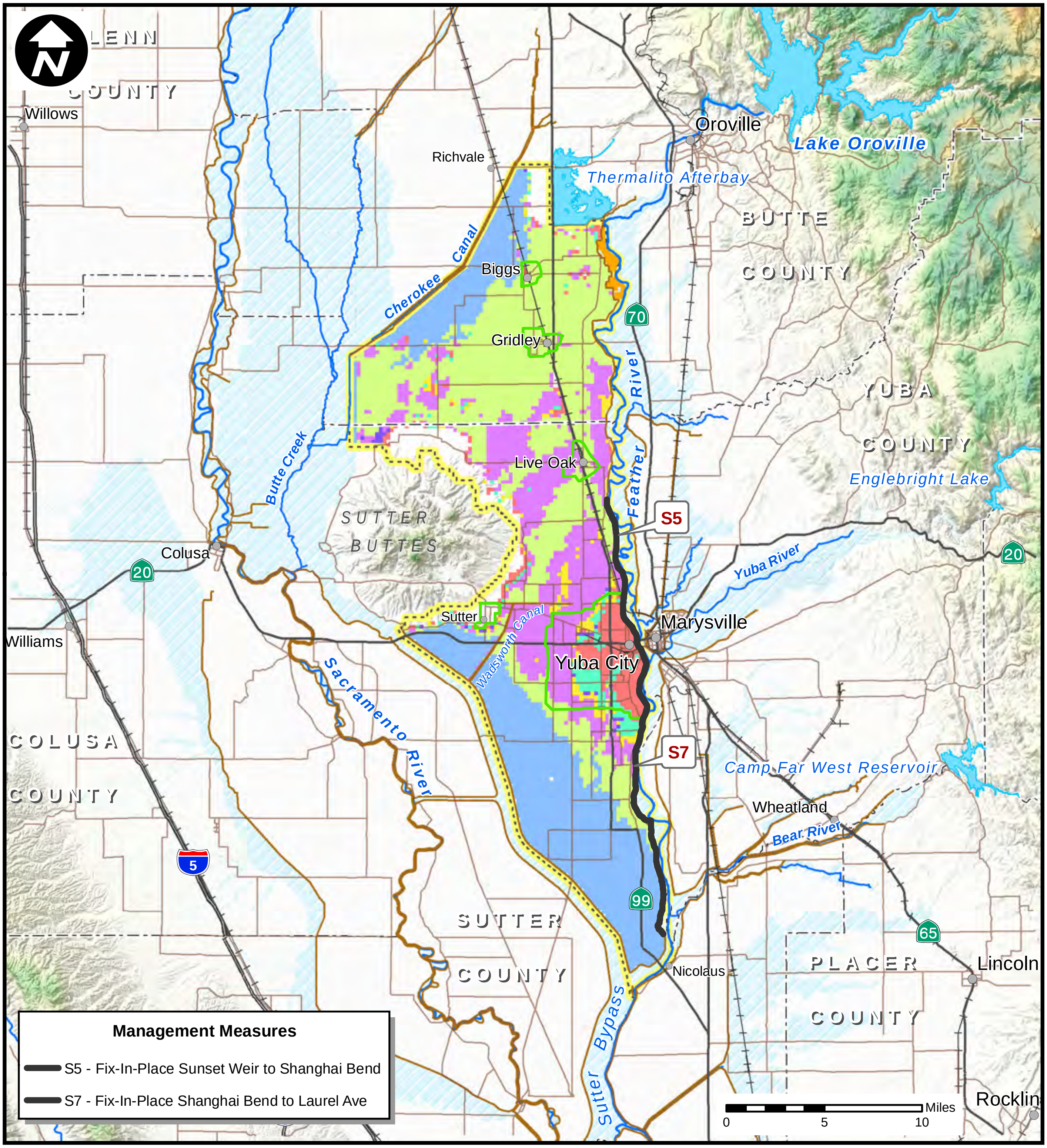
SUTTER BASIN PILOT FEASIBILITY STUDY
SUTTER BASIN, CALIFORNIA

CRITERIA 2 RESIDUAL FLOODPLAIN ALTERNATIVE SB-6 FIX IN PLACE FEATHER RIVER, SUTTER BYPASS, AND WADSWORTH

U.S. ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT

Prepared by Jim Mars

OCT 2012



Legend

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- 2% (1/50) ACE Floodplain
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- 50% (1/2) ACE Floodplain
- Federal Levee
- Study Area Extent
- Designated Floodways
- Lake or Reservoir
- River or Stream
- Railroad

Criteria 1 residual floodplain shown if geotechnical probability of failue is greater than 5% at median top of levee or top of levee less than 3 feet above median water surface elevation,

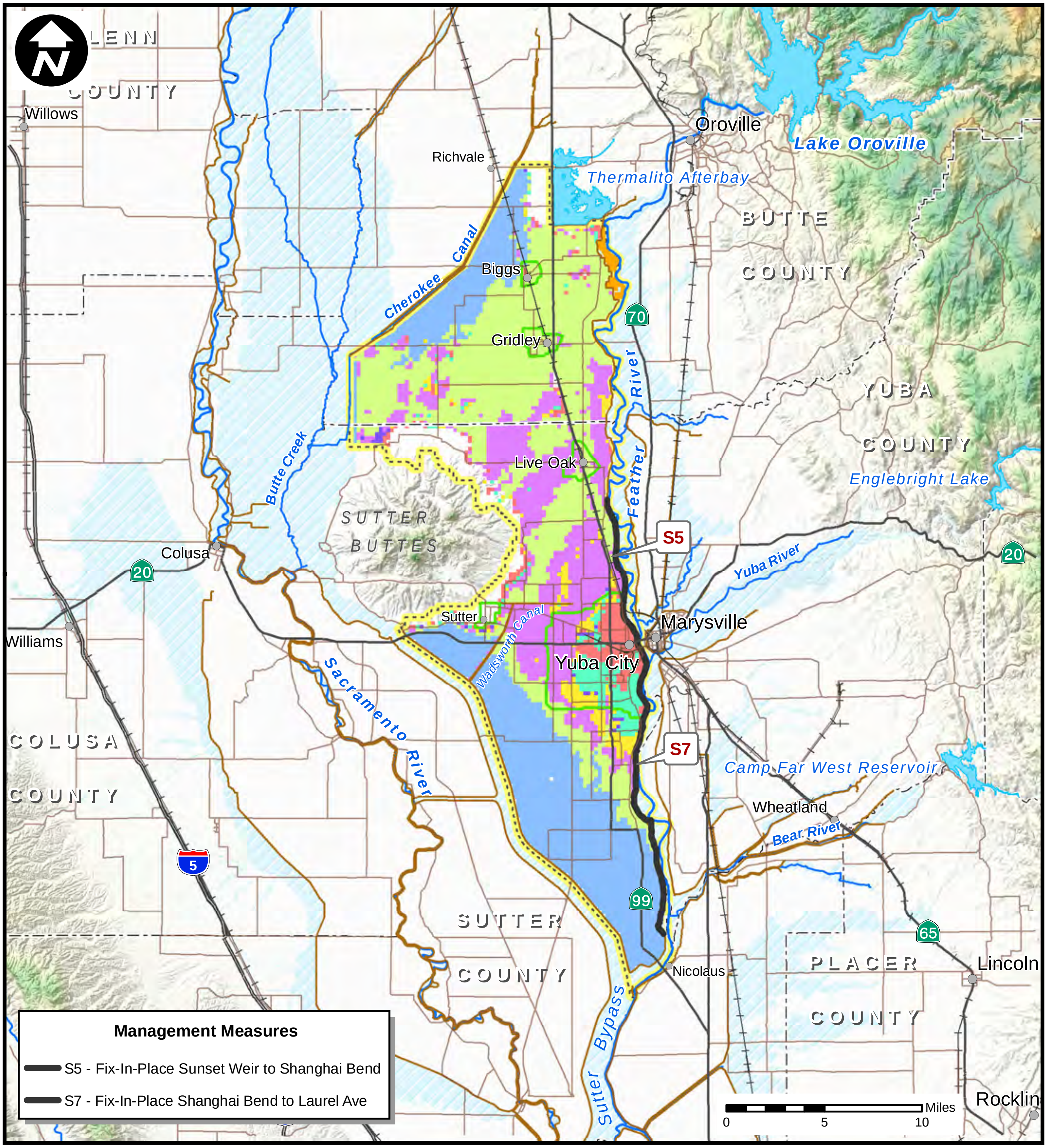
SUTTER BASIN PILOT FEASIBILITY STUDY
SUTTER BASIN, CALIFORNIA

CRITERIA 1 RESIDUAL FLOODPLAIN ALTERNATIVE SB-7 FIX-IN-PLACE FEATHER RIVER SUNSET WEIR TO LAUREL AVE

U.S. ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT

Prepared by Jim Mars

OCT 2012



Legend

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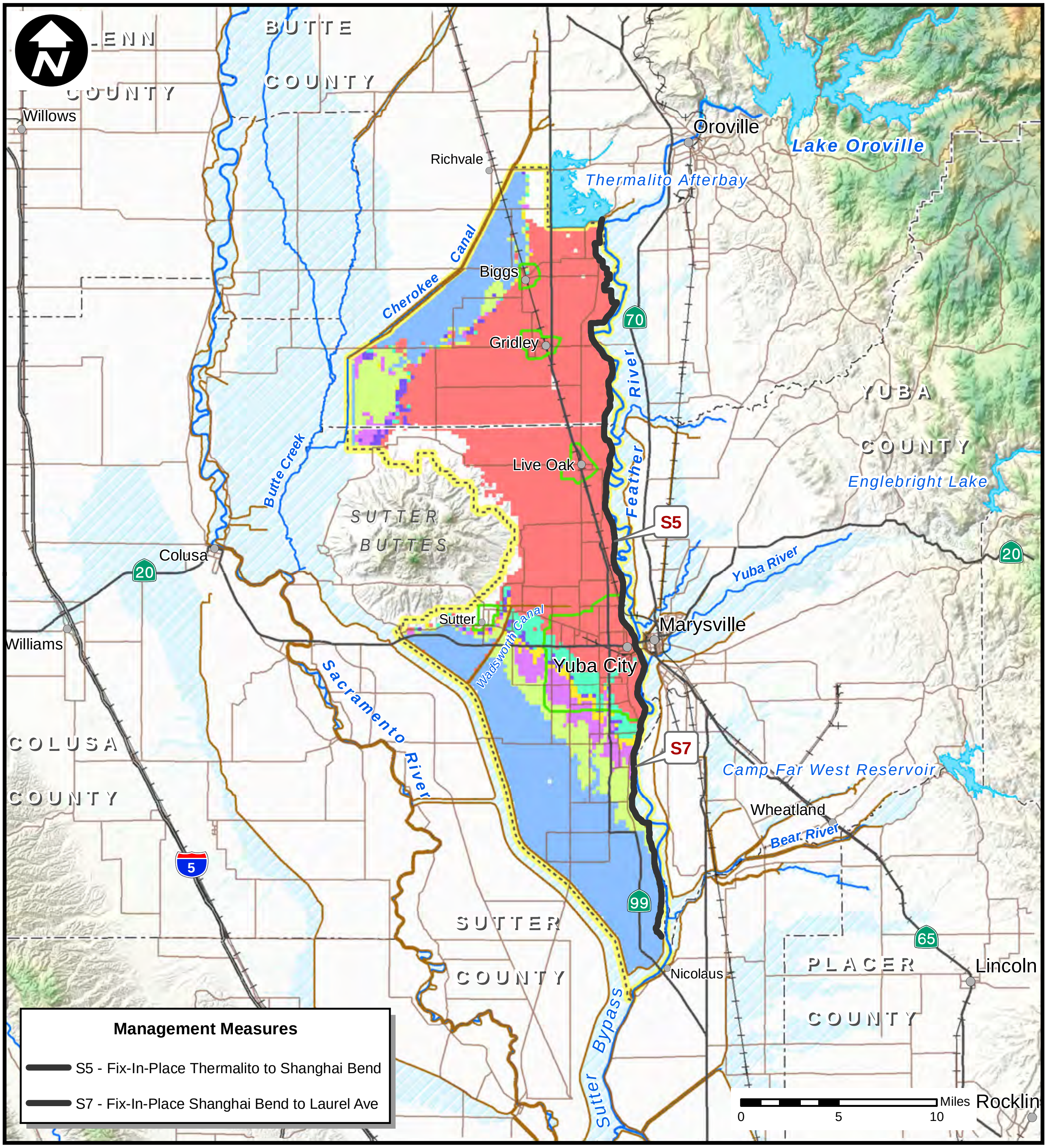
SUTTER BASIN PILOT FEASIBILITY STUDY
SUTTER BASIN, CALIFORNIA

CRITERIA 2 RESIDUAL FLOODPLAIN ALTERNATIVE SB-7 FIX-IN-PLACE FEATHER RIVER SUNSET WEIR TO LAUREL AVE

U.S. ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT

Prepared by Jim Mars

OCT 2012



Legend

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- 1% (1/100) AEP Floodplain
- 2% (1/50) ACE Floodplain
- 4% (1/25) ACE Floodplain
- 10% (1/10) ACE Floodplain
- 50% (1/2) ACE Floodplain
- Federal Levee
- Study Area Extent
- Designated Floodways
- Lake or Reservoir
- River or Stream
- Railroad

Criteria 1 residual floodplain shown if geotechnical probability of failue is greater than 5% at median top of levee or top of levee less than 3 feet above median water surface elevation,

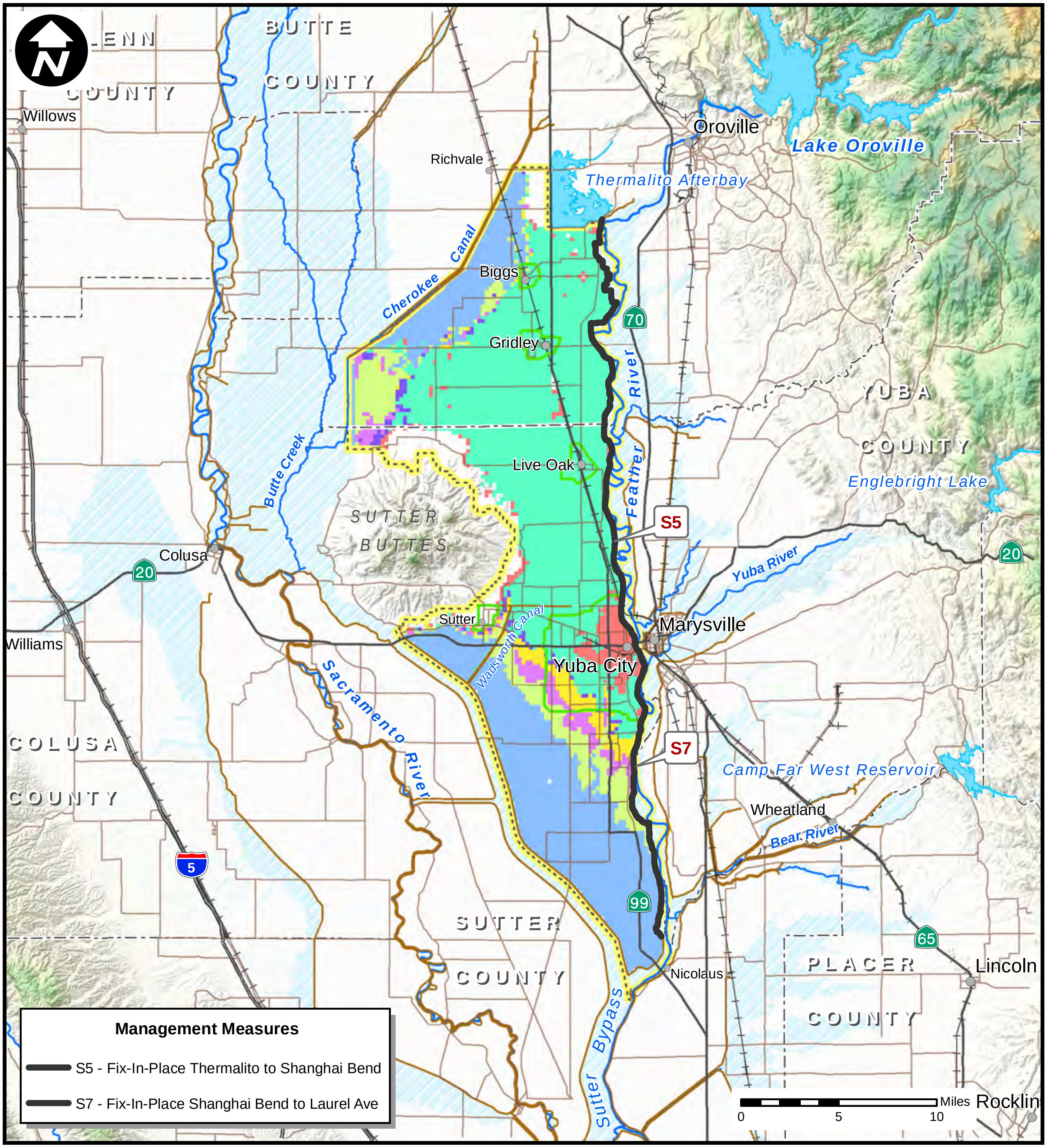
SUTTER BASIN PILOT FEASIBILITY STUDY
SUTTER BASIN, CALIFORNIA

CRITERIA 1 RESIDUAL FLOODPLAIN ALTERNATIVE SB-8 FIX IN PLACE FEATHER RIVER, THERMALITO TO LAUREL AVE

U.S. ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT

Prepared by Jim Mars

OCT 2012



Legend

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- 0.5% (1/200) ACE Floodplain
- 1% (1/100) AEP Floodplain
- 2% (1/50) ACE Floodplain
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SUTTER BASIN PILOT FEASIBILITY STUDY
SUTTER BASIN, CALIFORNIA

CRITERIA 2 RESIDUAL FLOODPLAIN ALTERNATIVE SB-8 FIX IN PLACE FEATHER RIVER, THERMALITO TO LAUREL AVE

U.S. ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT

Prepared by Jim Mars

OCT 2012

QUALITY CONTROL CERTIFICATE

Hydraulic Analysis Section, Engineering Division

PROJECT NAME: SUTTER BASIN, CALIFORNIA – PILOT FEASIBILITY STUDY
PRODUCT: MEMORANDUM FOR FILE: HYDRAULIC ANALYSIS OF REFINED ALTERNATIVES.
Actual Completion Date: 23-Oct-12

PROJECT MANAGER: LAURA WHITNEY

Background: [Include project description, technical products, and review methodology]

District Quality Control was performed on the 23 October revision to the memorandum originally dated 8 June 2012. The purpose of the revision was to include two additional alternatives SB-7 and SB-8.

HYDRAULIC LEAD

I have ensured that the above products were prepared in accordance with standard quality control practices. I have also incorporated or resolved all issues identified during District Quality Control (DQC) review.

Hydraulic Lead: Peter Blodgett	Title: Senior Hydraulic Engineer PETER BLODGETT	10/26/2012
Print name	Signature	Date

REVIEWERS

I have reviewed the products noted above and find them to be in accordance with project requirements, standards of the profession, and USACE policies and standards.

DQC Reviewer: John Wiest JOHN C WIEST	Title: Hydraulic Engineer	10/26/12
Print name	Signature	Date

RESOURCE PROVIDER

I have reviewed and resolved all critical and technical issues. I agree that all project requirements, standards of the profession, and USACE policies and standards have been met.

Section Chief: Peter Blodgett Peter Blodgett		10/26/2012
Print name	Signature	Date

ATTACHMENT B

Final Geotechnical Fragility Curves

February 2013.

Geotechnical Risk and Uncertainty Analysis - Taylor Series Method
Combined Probability of Poor Performance Curve

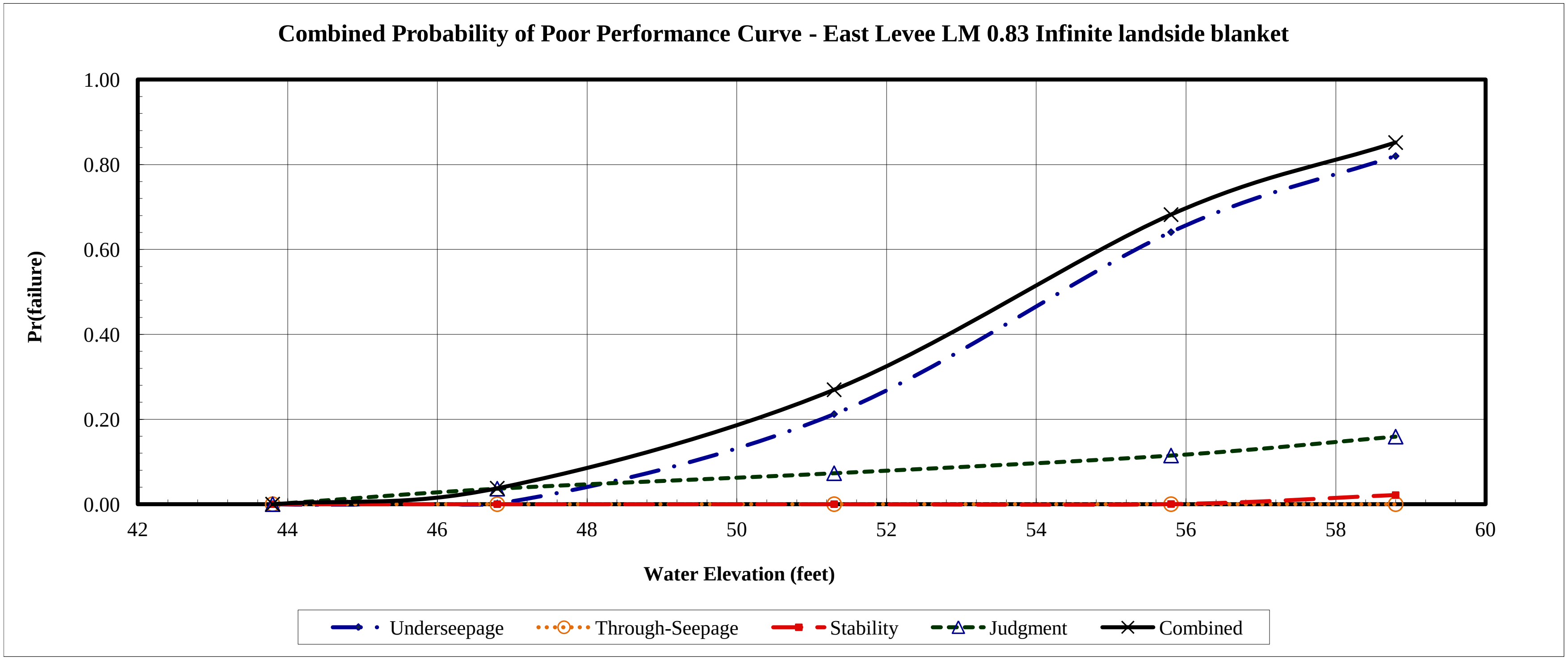
Project: Sutter Feasibility Study
Study Area: Wadsworth Canal
River Section: East Levee

Levee Mile: 0.83
River Mile: 2170954.86 N; (
Analysis Case: Infinite landside blanket

Crest Elev.: 58.80
L/S Toe Elev.: 43.80
W/S Toe Elev.: 41.80

Analysis By: T. Huynh
Checked By: E.W. James/J.M.
Date: Updated 9/13/20

Water Surface Elevation	Underseepage		Through-Seepage		Stability		Judgment		Combined	
	Pr(f)	R	Pr(f)	R	Pr(f)	R	Pr(f)	R	Pr(f)	R
43.80	0.0000	1.0000	0.0000	1.0000	0.0000	1.0000	0.0000	1.0000	0.0000	1.0000
46.80	0.0011	0.9989	0.0000	1.0000	0.0000	1.0000	0.0365	0.9635	0.0375	0.9625
51.30	0.2121	0.7879	0.0000	1.0000	0.0000	1.0000	0.0729	0.9271	0.2695	0.7305
55.80	0.6407	0.3593	0.0000	1.0000	0.0003	0.9997	0.1145	0.8855	0.6820	0.3180
58.80	0.8199	0.1801	0.0000	1.0000	0.0213	0.9787	0.1590	0.8410	0.8518	0.1482



Geotechnical Risk and Uncertainty Analysis - Taylor Series Method
Combined Probability of Poor Performance Curve

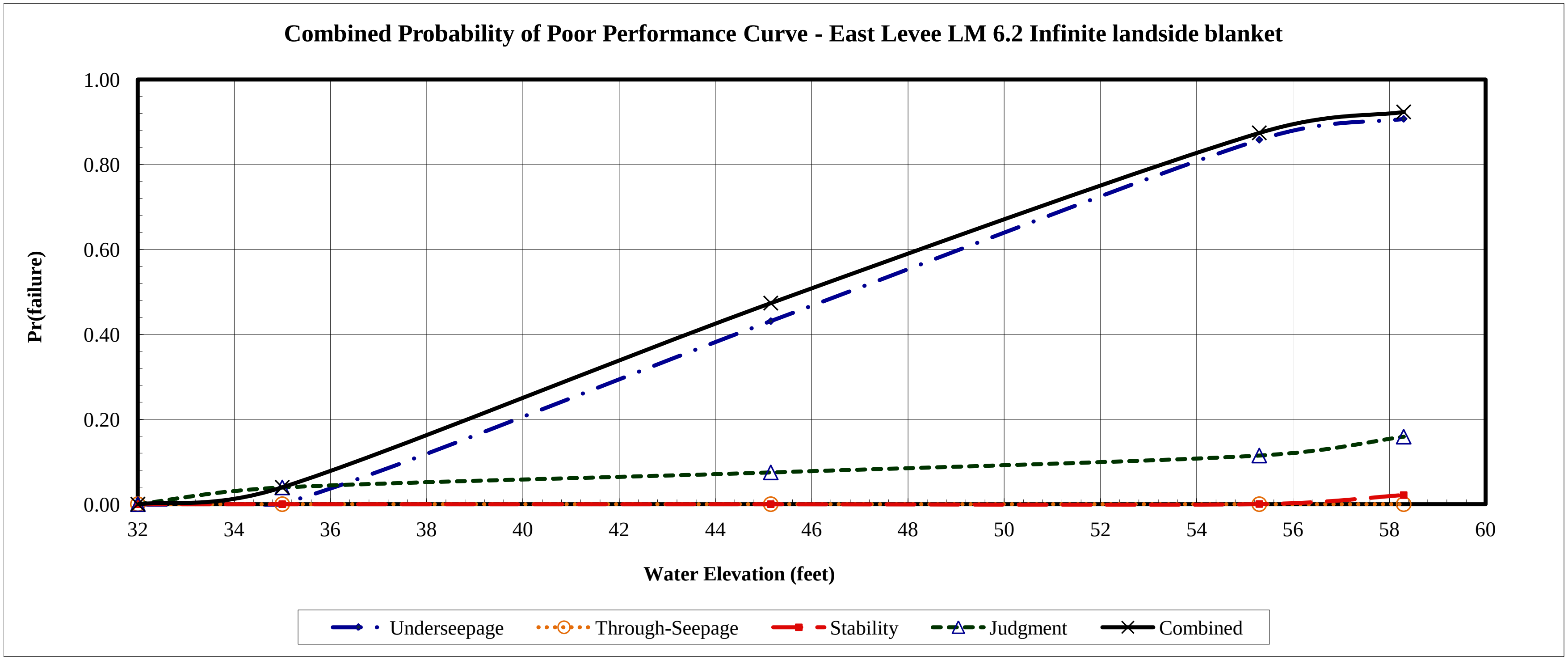
Project: Sutter Feasibility Study
Study Area: Sutter Bypass
River Section: East Levee

Levee Mile: 6.20
River Mile: 2158855 N; 663
Analysis Case: Infinite landside blanket

Crest Elev.: 58.30
L/S Toe Elev.: 32.00
W/S Toe Elev.: 32.00

Analysis By: T. Huynh
Checked By: E.W. James/J.M.
Date: 9/13/2012

Water Surface Elevation	Underseepage		Through-Seepage		Stability		Judgment		Combined	
	Pr(f)	R	Pr(f)	R	Pr(f)	R	Pr(f)	R	Pr(f)	R
32.00	0.0000	1.0000	0.0000	1.0000	0.0000	1.0000	0.0000	1.0000	0.0000	1.0000
35.00	0.0004	0.9996	0.0000	1.0000	0.0000	1.0000	0.0394	0.9606	0.0398	0.9602
45.15	0.4311	0.5689	0.0000	1.0000	0.0000	1.0000	0.0747	0.9253	0.4736	0.5264
55.30	0.8583	0.1417	0.0000	1.0000	0.0003	0.9997	0.1145	0.8855	0.8746	0.1254
58.30	0.9076	0.0924	0.0000	1.0000	0.0213	0.9787	0.1590	0.8410	0.9239	0.0761



Geotechnical Risk and Uncertainty Analysis - Taylor Series Method
Combined Probability of Poor Performance Curve

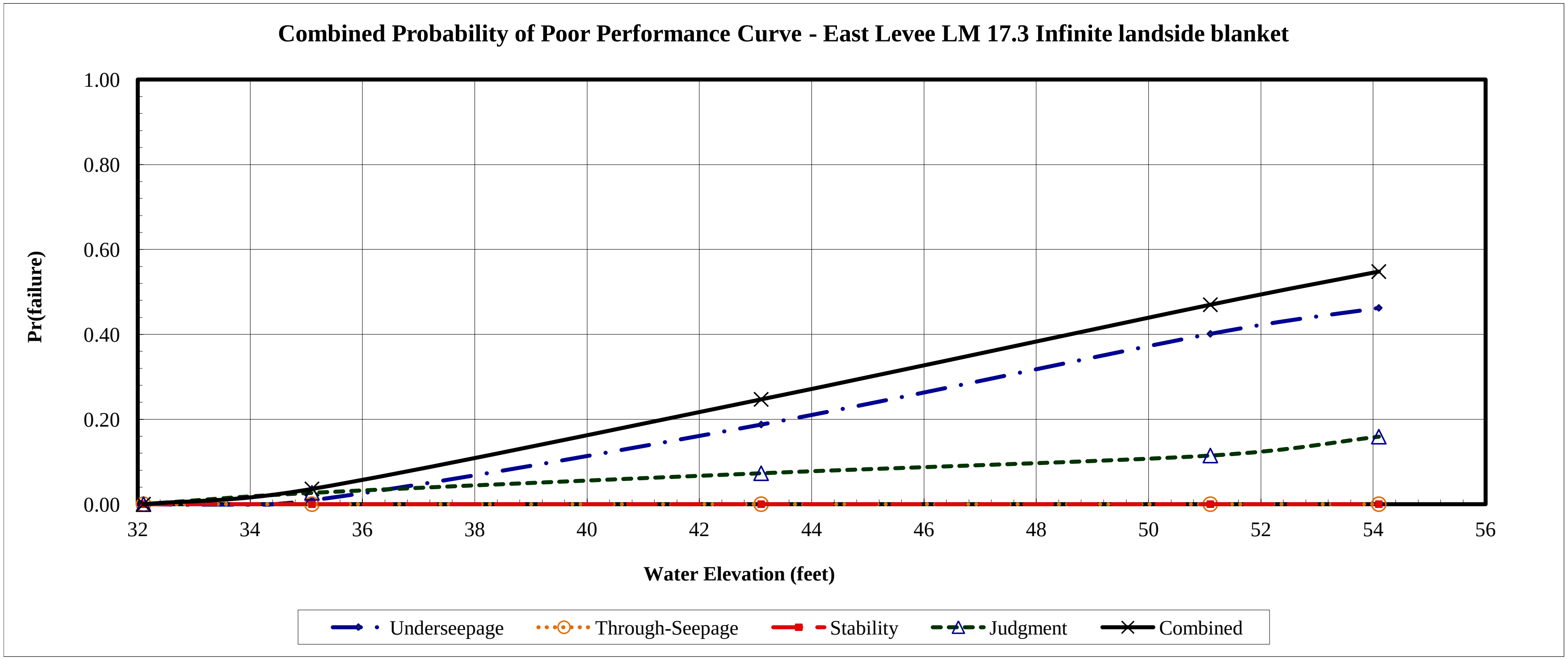
Project: Sutter Feasibility Study
Study Area: Sutter Bypass
River Section: East Levee

Levee Mile: 17.30
River Mile: 2113476.9763 N
Analysis Case: Infinite landside blanket

Crest Elev.: 54.10
L/S Toe Elev.: 32.10
W/S Toe Elev.: 37.78

Analysis By: T. Huynh
Checked By: E.W. James/J.M.
Date: Updated 13 Augu

Water Surface Elevation	Underseepage		Through-Seepage		Stability		Judgment		Combined	
	Pr(f)	R	Pr(f)	R	Pr(f)	R	Pr(f)	R	Pr(f)	R
32.10	0.0000	1.0000	0.0000	1.0000	0.0000	1.0000	0.0000	1.0000	0.0000	1.0000
35.10	0.0094	0.9906	0.0000	1.0000	0.0000	1.0000	0.0267	0.9733	0.0359	0.9641
43.10	0.1876	0.8124	0.0000	1.0000	0.0000	1.0000	0.0729	0.9271	0.2468	0.7532
51.10	0.4011	0.5989	0.0000	1.0000	0.0000	1.0000	0.1145	0.8855	0.4697	0.5303
54.10	0.4623	0.5377	0.0000	1.0000	0.0001	0.9999	0.1590	0.8410	0.5478	0.4522



Geotechnical Risk and Uncertainty Analysis - Taylor Series Method
Combined Probability of Poor Performance Curve

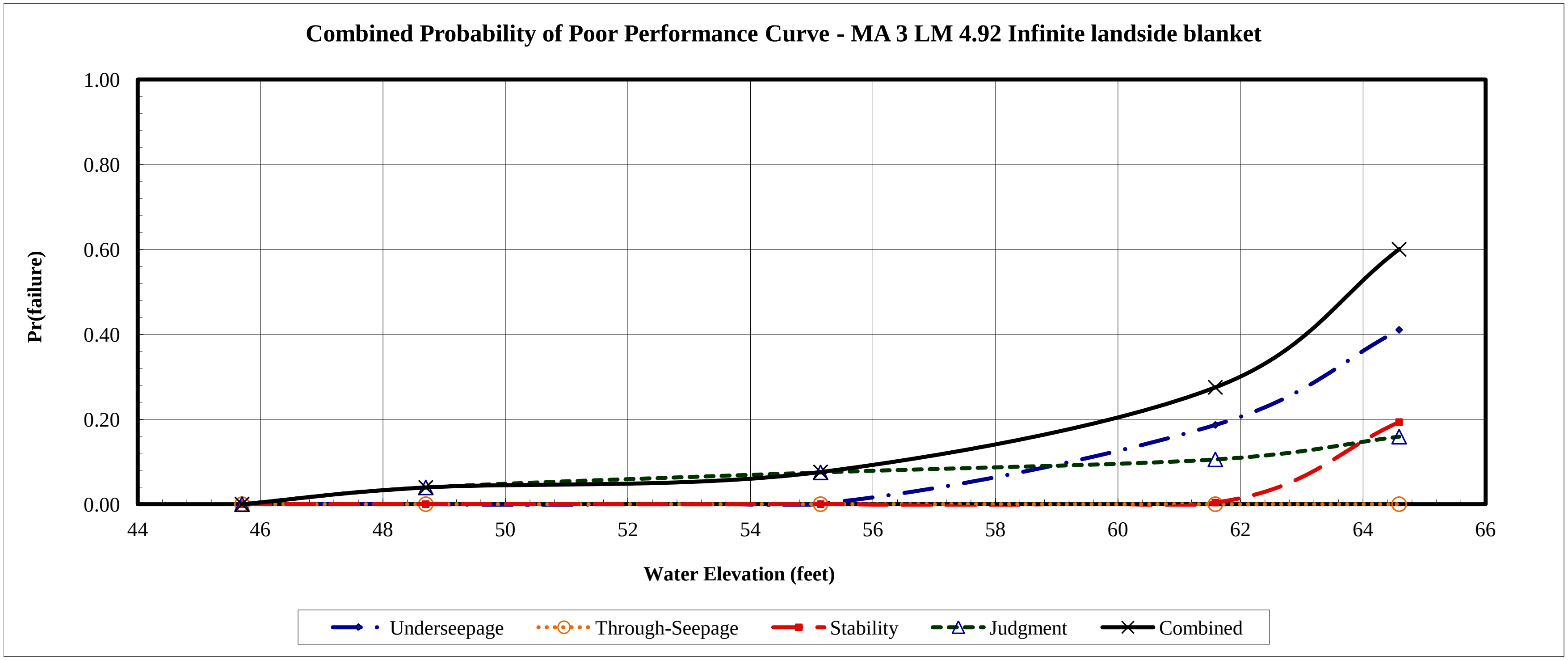
Project: Sutter Feasibility Study
Study Area: Feather River South
River Section: MA 3

Levee Mile: 4.92
River Mile: 2106963.58 N; (
Analysis Case: Infinite landside blanket

Crest Elev.: 64.59
L/S Toe Elev.: 45.70
W/S Toe Elev.: 45.00

Analysis By: T. Huynh
Checked By: E.W. James/J.M.
Date: Updated 09/12/2(

Water Surface Elevation	Underseepage		Through-Seepage		Stability		Judgment		Combined	
	Pr(f)	R	Pr(f)	R	Pr(f)	R	Pr(f)	R	Pr(f)	R
45.70	0.0000	1.0000	0.0000	1.0000	0.0000	1.0000	0.0000	1.0000	0.0000	1.0000
48.70	0.0000	1.0000	0.0000	1.0000	0.0000	1.0000	0.0394	0.9606	0.0394	0.9606
55.15	0.0011	0.9989	0.0000	1.0000	0.0000	1.0000	0.0747	0.9253	0.0758	0.9242
61.59	0.1867	0.8133	0.0000	1.0000	0.0038	0.9962	0.1054	0.8946	0.2751	0.7249
64.59	0.4106	0.5894	0.0000	1.0000	0.1934	0.8066	0.1590	0.8410	0.6002	0.3998



Geotechnical Risk and Uncertainty Analysis - Taylor Series Method
Combined Probability of Poor Performance Curve

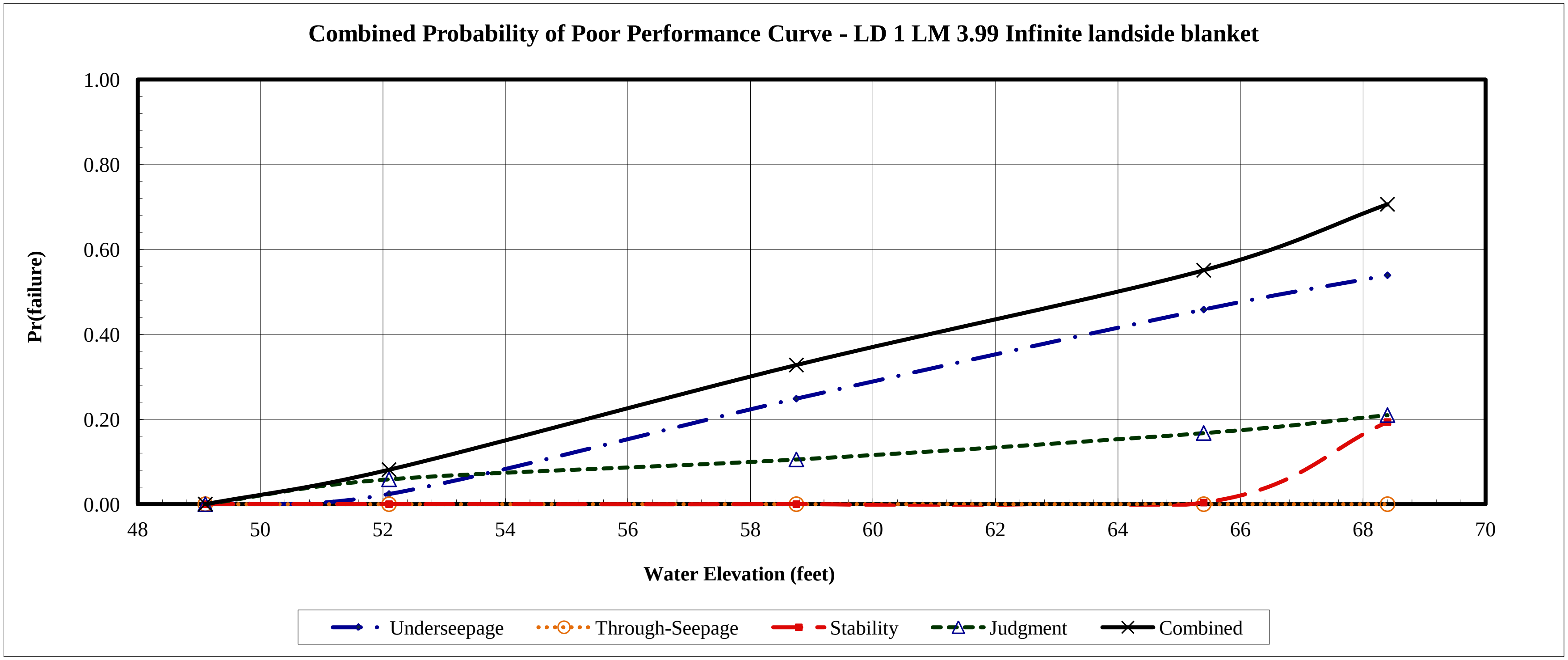
Project: Sutter Feasibility Study
Study Area: Feather River South
River Section: LD 1

Levee Mile: 3.99
River Mile: 2127081.8143 N
Analysis Case: Infinite landside blanket

Crest Elev.: 68.40
L/S Toe Elev.: 49.10
W/S Toe Elev.: 40.00

Analysis By: T. Huynh
Checked By: E.W. James\J.M.
Date: Updated 09/26/2(

Water Surface Elevation	Underseepage		Through-Seepage		Stability		Judgment		Combined	
	Pr(f)	R	Pr(f)	R	Pr(f)	R	Pr(f)	R	Pr(f)	R
49.10	0.0000	1.0000	0.0000	1.0000	0.0000	1.0000	0.0000	1.0000	0.0000	1.0000
52.10	0.0240	0.9760	0.0000	1.0000	0.0000	1.0000	0.0586	0.9414	0.0812	0.9188
58.75	0.2485	0.7515	0.0000	1.0000	0.0000	1.0000	0.1053	0.8947	0.3276	0.6724
65.40	0.4584	0.5416	0.0000	1.0000	0.0038	0.9962	0.1676	0.8324	0.5509	0.4491
68.40	0.5390	0.4610	0.0000	1.0000	0.1934	0.8066	0.2098	0.7902	0.7062	0.2938



Geotechnical Risk and Uncertainty Analysis - Taylor Series Method
Combined Probability of Poor Performance Curve

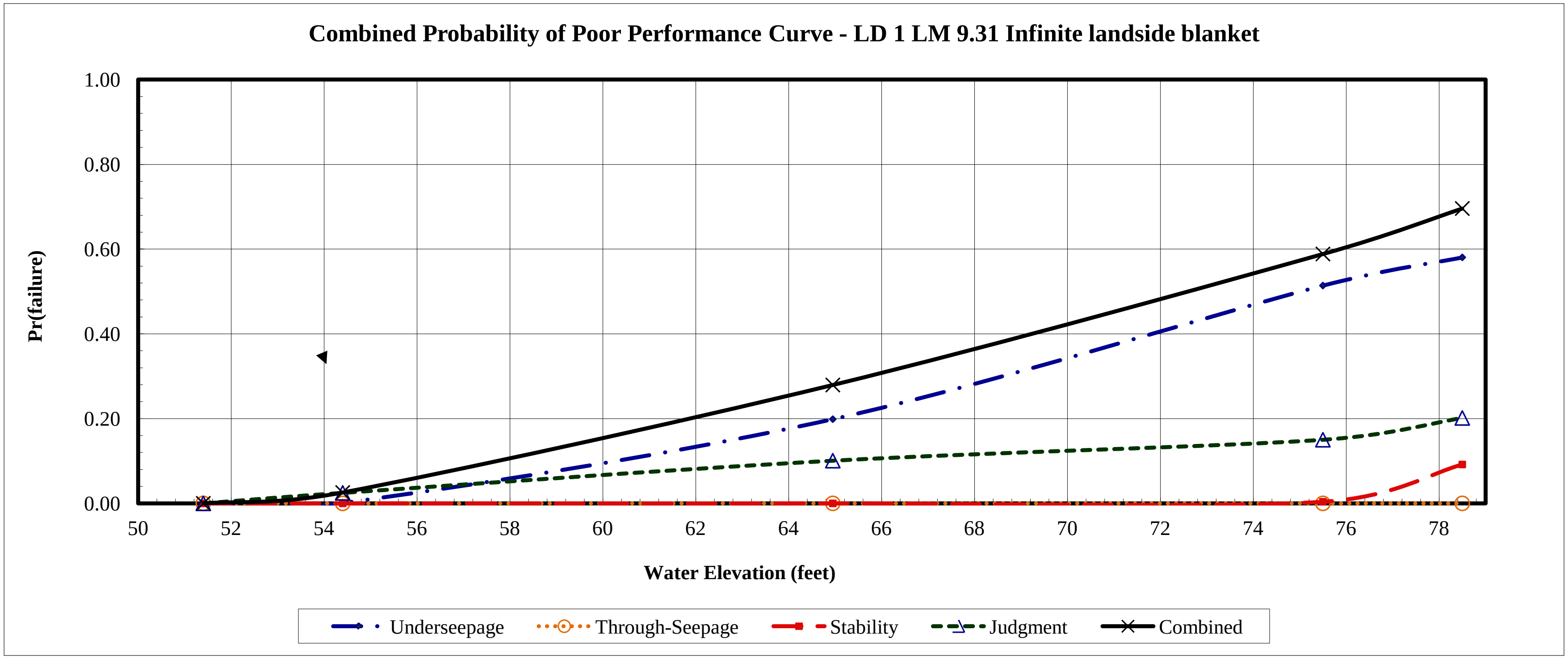
Project: Sutter Feasibility Study
Study Area: Feather River South
River Section: LD 1

Levee Mile: 9.31
River Mile: 2156078.18 N; (
Analysis Case: Infinite landside blanket

Crest Elev.: 78.50
L/S Toe Elev.: 51.40
W/S Toe Elev.: 53.70

Analysis By: T. Huynh
Checked By: E.W. James/J.M.
Date: Updated 2/21/20

Water Surface Elevation	Underseepage		Through-Seepage		Stability		Judgment		Combined	
	Pr(f)	R	Pr(f)	R	Pr(f)	R	Pr(f)	R	Pr(f)	R
51.40	0.0000	1.0000	0.0000	1.0000	0.0000	1.0000	0.0000	1.0000	0.0000	1.0000
54.40	0.0008	0.9992	0.0000	1.0000	0.0000	1.0000	0.0248	0.9752	0.0255	0.9745
64.95	0.1986	0.8014	0.0000	1.0000	0.0000	1.0000	0.1007	0.8993	0.2793	0.7207
75.50	0.5140	0.4860	0.0000	1.0000	0.0038	0.9962	0.1501	0.8499	0.5885	0.4115
78.50	0.5805	0.4195	0.0000	1.0000	0.0917	0.9083	0.2015	0.7985	0.6958	0.3042



Geotechnical Risk and Uncertainty Analysis - Taylor Series Method
Combined Probability of Poor Performance Curve

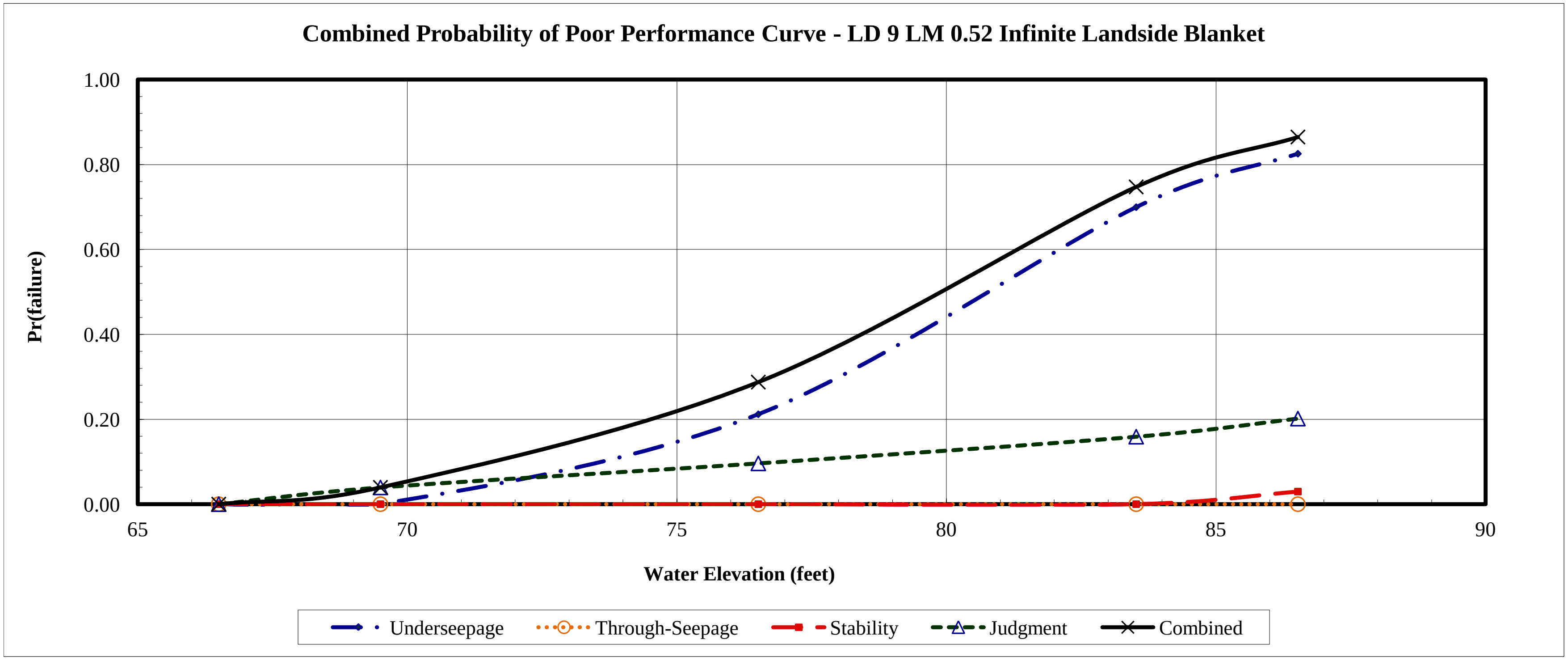
Project: Sutter Feasibility Study
Study Area: Feather River South
River Section: LD 9

Levee Mile: 0.52
River Mile: 2188213.88 N; (
Analysis Case: Infinite landside blanket

Crest Elev.: 86.52
L/S Toe Elev.: 66.50
W/S Toe Elev.: 58.90

Analysis By: T. Huynh
Checked By: E.W. James/J.M.
Date: Updated 9/12/20

Water Surface Elevation	Underseepage		Through-Seepage		Stability		Judgment		Combined	
	Pr(f)	R	Pr(f)	R	Pr(f)	R	Pr(f)	R	Pr(f)	R
66.50	0.0000	1.0000	0.0000	1.0000	0.0000	1.0000	0.0000	1.0000	0.0000	1.0000
69.50	0.0001	0.9999	0.0000	1.0000	0.0000	1.0000	0.0394	0.9606	0.0394	0.9606
76.51	0.2117	0.7883	0.0000	1.0000	0.0000	1.0000	0.0961	0.9039	0.2875	0.7125
83.52	0.6995	0.3005	0.0000	1.0000	0.0000	1.0000	0.1589	0.8411	0.7473	0.2527
86.52	0.8254	0.1746	0.0000	1.0000	0.0297	0.9703	0.2015	0.7985	0.8647	0.1353



Geotechnical Risk and Uncertainty Analysis - Taylor Series Method
Combined Probability of Poor Performance Curve

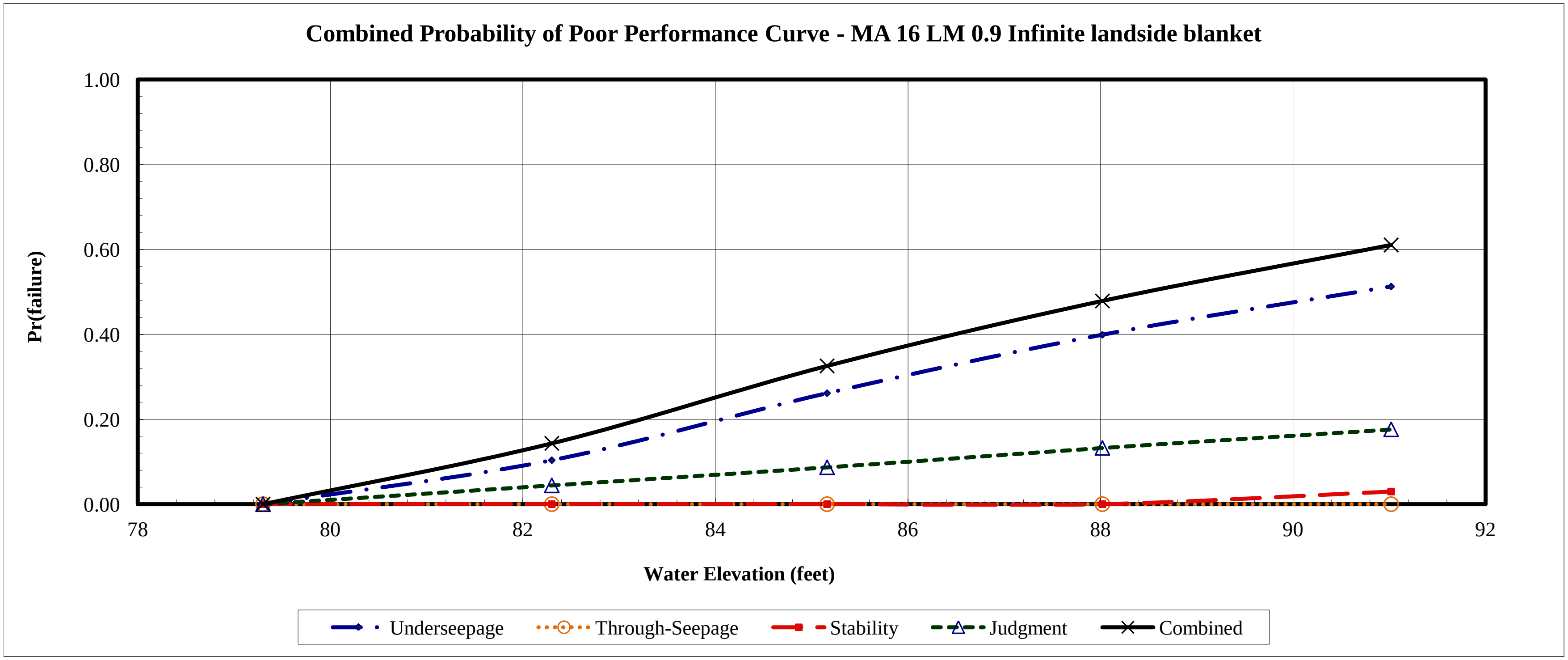
Project: Sutter Feasibility Study
Study Area: Feather River North
River Section: MA 16

Levee Mile: 0.90
River Mile: 2224154.37 N; (
Analysis Case: Infinite landside blanket

Crest Elev.: 91.02
L/S Toe Elev.: 79.30
W/S Toe Elev.: 77.30

Analysis By: T. Huynh
Checked By: E.W. James/J.M.
Date: Updated 9/12/20

Water Surface Elevation	Underseepage		Through-Seepage		Stability		Judgment		Combined	
	Pr(f)	R	Pr(f)	R	Pr(f)	R	Pr(f)	R	Pr(f)	R
79.30	0.0000	1.0000	0.0000	1.0000	0.0000	1.0000	0.0000	1.0000	0.0000	1.0000
82.30	0.1036	0.8964	0.0000	1.0000	0.0000	1.0000	0.0442	0.9558	0.1432	0.8568
85.16	0.2614	0.7386	0.0000	1.0000	0.0000	1.0000	0.0869	0.9131	0.3256	0.6744
88.02	0.3990	0.6010	0.0000	1.0000	0.0000	1.0000	0.1324	0.8676	0.4786	0.5214
91.02	0.5127	0.4873	0.0000	1.0000	0.0297	0.9703	0.1761	0.8239	0.6105	0.3895



Geotechnical Risk and Uncertainty Analysis - Taylor Series Method
Combined Probability of Poor Performance Curve

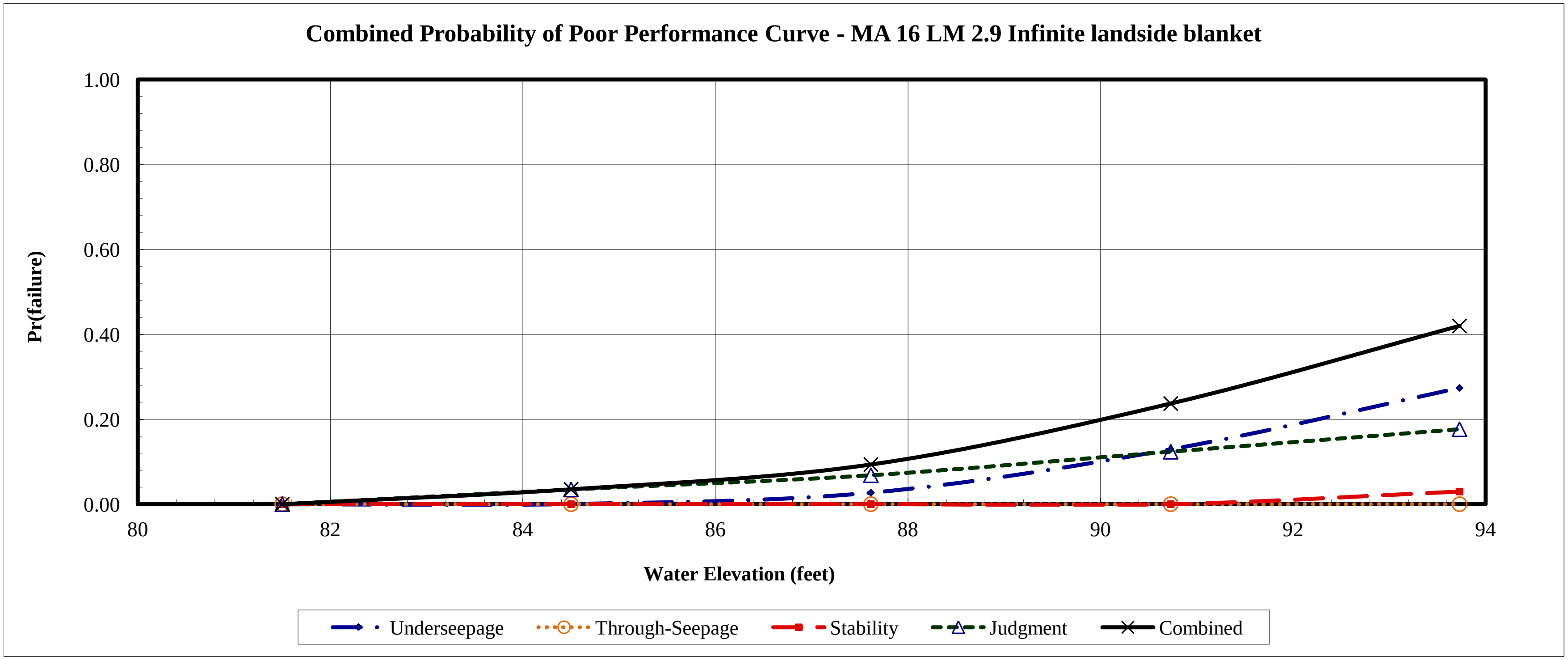
Project: Sutter Feasibility Study
Study Area: Feather River North
River Section: MA 16

Levee Mile: 2.90
River Mile: 2233626.25 N; (
Analysis Case: Infinite landside blanket

Crest Elev.: 93.73
L/S Toe Elev.: 81.50
W/S Toe Elev.: 79.40

Analysis By: T. Huynh
Checked By: E.W. James/J.M.
Date: Updated 9/12/20

Water Surface Elevation	Underseepage		Through-Seepage		Stability		Judgment		Combined	
	Pr(f)	R	Pr(f)	R	Pr(f)	R	Pr(f)	R	Pr(f)	R
81.50	0.0000	1.0000	0.0000	1.0000	0.0000	1.0000	0.0000	1.0000	0.0000	1.0000
84.50	0.0005	0.9995	0.0000	1.0000	0.0000	1.0000	0.0345	0.9655	0.0350	0.9650
87.62	0.0271	0.9729	0.0000	1.0000	0.0000	1.0000	0.0681	0.9319	0.0934	0.9066
90.73	0.1294	0.8706	0.0000	1.0000	0.0000	1.0000	0.1235	0.8765	0.2369	0.7631
93.73	0.2738	0.7262	0.0000	1.0000	0.0297	0.9703	0.1762	0.8238	0.4195	0.5805



Geotechnical Risk and Uncertainty Analysis - Taylor Series Method
Combined Probability of Poor Performance Curve

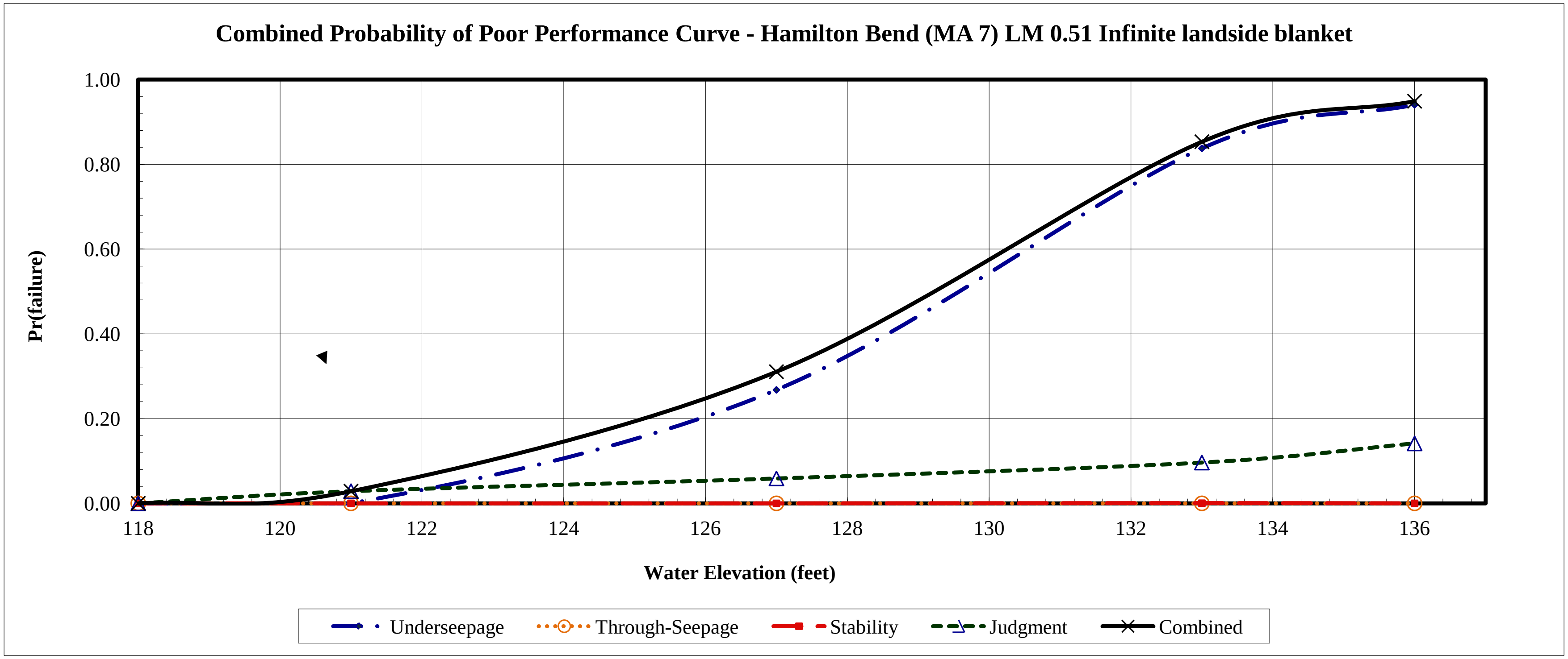
Project: Sutter Feasibility Study
Study Area: Feather River North
River Section: Hamilton Bend (MA 7)

Levee Mile: 0.51
River Mile: 2288660.96 N; (
Analysis Case: Infinite landside blanket

Crest Elev.: 136.00
L/S Toe Elev.: 118.00
W/S Toe Elev.: 118.00

Analysis By: T. Huynh
Checked By: E.W. James/J.M.
Date: Updated 2/21/20

Water Surface Elevation	Underseepage		Through-Seepage		Stability		Judgment		Combined	
	Pr(f)	R	Pr(f)	R	Pr(f)	R	Pr(f)	R	Pr(f)	R
118.00	0.0000	1.0000	0.0000	1.0000	0.0000	1.0000	0.0000	1.0000	0.0000	1.0000
121.00	0.0000	1.0000	0.0000	1.0000	0.0000	1.0000	0.0287	0.9713	0.0287	0.9713
127.00	0.2678	0.7322	0.0000	1.0000	0.0000	1.0000	0.0587	0.9413	0.3108	0.6892
133.00	0.8376	0.1624	0.0000	1.0000	0.0003	0.9997	0.0963	0.9037	0.8533	0.1467
136.00	0.9405	0.0595	0.0000	1.0000	0.0000	1.0000	0.1414	0.8586	0.9489	0.0511



Geotechnical Risk and Uncertainty Analysis - Taylor Series Method
Combined Probability of Poor Performance Curve

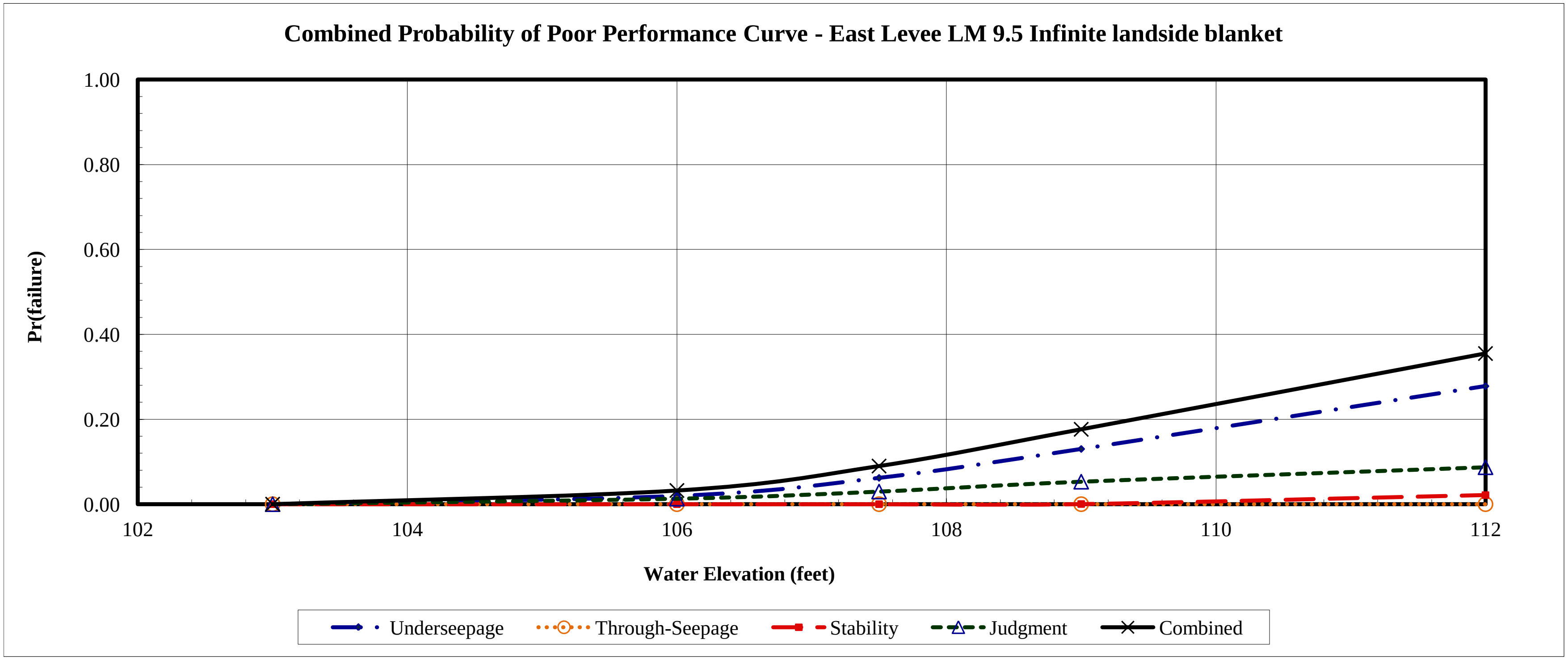
Project: Sutter Feasibility Study
Study Area: Cherokee Canal
River Section: East Levee

Levee Mile: 9.50
River Mile: 2301045.948 N:
Analysis Case: Infinite landside blanket

Crest Elev.: 112.00
L/S Toe Elev.: 103.00
W/S Toe Elev.: 104.00

Analysis By: T. Huynh
Checked By: E.W. James/J.M.
Date: Updated 9/13/12

Water Surface Elevation	Underseepage		Through-Seepage		Stability		Judgment		Combined	
	Pr(f)	R	Pr(f)	R	Pr(f)	R	Pr(f)	R	Pr(f)	R
103.00	0.0000	1.0000	0.0000	1.0000	0.0000	1.0000	0.0000	1.0000	0.0000	1.0000
106.00	0.0195	0.9805	0.0000	1.0000	0.0000	1.0000	0.0129	0.9871	0.0322	0.9678
107.50	0.0620	0.9380	0.0000	1.0000	0.0000	1.0000	0.0297	0.9703	0.0898	0.9102
109.00	0.1300	0.8700	0.0000	1.0000	0.0003	0.9997	0.0529	0.9471	0.1763	0.8237
112.00	0.2780	0.7220	0.0000	1.0000	0.0213	0.9787	0.0870	0.9130	0.3548	0.6452



Geotechnical Risk and Uncertainty Analysis - Taylor Series Method
Combined Probability of Poor Performance Curve

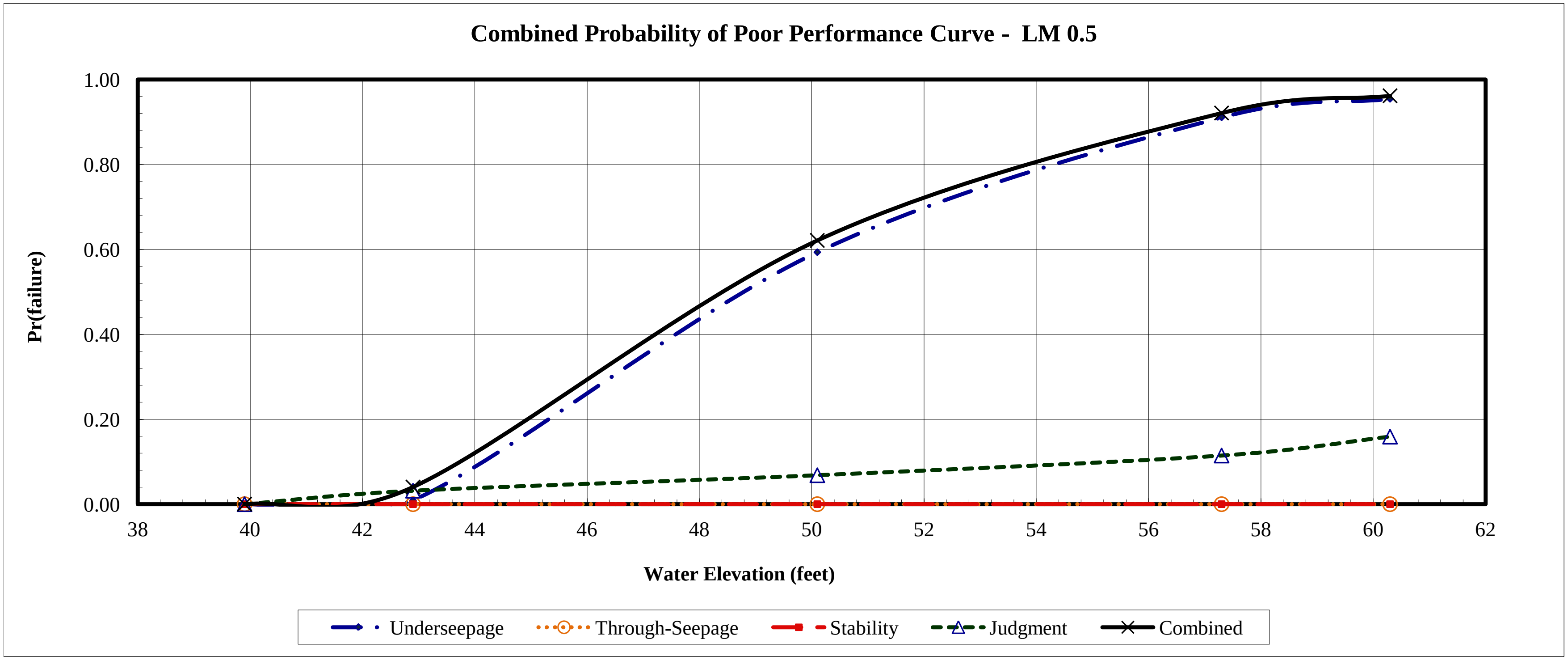
Project: Sutter Feasibility Study
Study Area: Wadsworth Canal - Right Bank
River Section:

Levee Mile: 0.50
River Mile: 2168750 N; 662
Analysis Case:

Crest Elev.: 60.30
L/S Toe Elev.: 39.90
W/S Toe Elev.: 41.50

Analysis By: E.W. James
Checked By: J.M. Bolton
Date: Updated 09/14/:

Water Surface Elevation	Underseepage		Through-Seepage		Stability		Judgment		Combined	
	Pr(f)	R	Pr(f)	R	Pr(f)	R	Pr(f)	R	Pr(f)	R
39.90	0.0000	1.0000	0.0000	1.0000	0.0000	1.0000	0.0000	1.0000	0.0000	1.0000
42.90	0.0088	0.9912	0.0000	1.0000	0.0000	1.0000	0.0316	0.9684	0.0402	0.9598
50.10	0.5935	0.4065	0.0000	1.0000	0.0000	1.0000	0.0682	0.9318	0.6212	0.3788
57.30	0.9112	0.0888	0.0000	1.0000	0.0000	1.0000	0.1145	0.8855	0.9213	0.0787
60.30	0.9547	0.0453	0.0000	1.0000	0.0000	1.0000	0.1590	0.8410	0.9619	0.0381



Geotechnical Risk and Uncertainty Analysis - Taylor Series Method
Combined Probability of Poor Performance Curve

Project: Sutter Feasibility Study
Study Area: Sutter Bypass
River Section: Left Levee

Levee Mile: 4.00
River Mile: 2168110 N; 662
Analysis Case: Infinite waterside/landside blanket

Crest Elev.: 60.60
L/S Toe Elev.: 39.90
W/S Toe Elev.: 41.50

Analysis By: T. Huynh
Checked By: E.W. James/J.M.
Date: Updated 9/14/20

Water Surface Elevation	Underseepage		Through-Seepage		Stability		Judgment		Combined	
	Pr(f)	R	Pr(f)	R	Pr(f)	R	Pr(f)	R	Pr(f)	R
39.90	0.0000	1.0000	0.0000	1.0000	0.0000	1.0000	0.0000	1.0000	0.0000	1.0000
42.90	0.0004	0.9996	0.0000	1.0000	0.0000	1.0000	0.0394	0.9606	0.0398	0.9602
50.25	0.2366	0.7634	0.0000	1.0000	0.0005	0.9995	0.0747	0.9253	0.2940	0.7060
57.60	0.6780	0.3220	0.0000	1.0000	0.6959	0.3041	0.1145	0.8855	0.9133	0.0867
60.60	0.7846	0.2154	0.0000	1.0000	0.8754	0.1246	0.1590	0.8410	0.9774	0.0226